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AND ABSTRACT OF THE LITERATURE

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Silicosis and Tuberculosis as Seen in the Granite Workers in Barre, Vt.

Metal Fume Fever: IV. Threshold Doses of Zinc Oxide, Preventive Measures, and the Chronic Effects of Repeated Exposures

The Storage Battery Industry

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SILICOSIS AND TUBERCULOSIS AS SEEN IN THE GRANITE WORKERS IN BARRE, VT.*

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Barre, Vt.

GENERAL CONSIDERATIONS

THE physicians of Vermont should be greatly interested in the condition known as pneumonokoniosis, particularly silicosis, as it is quite prevalent in the various granite cutting centers of the state. The production of granite is one of the leading industries of Vermont; the health of the granite workers is therefore an important matter because the future of the industry depends on it. Workers in this industry who become ill from the effects of their trades go to their physicians for diagnosis and treatment. Silicosis, being an occupational disease, is compensable in a number of states and is already under consideration in Vermont. In the event that it is made compensable, it will be the physician's duty to make a diagnosis of the condition and to determine the extent to which it has disabled the worker. These are the reasons why I consider a thorough knowledge of silicosis so important to the physicians of Vermont.

According to the report of T. Nelson Dale, of the United States Geological Survey (1), the following places in the state produce granite:

Barre	Newark
Woodbury	Topsham
Reygate	Windsor
Rochester	Randolph
Williamstown	Derby
Kirby	Barton
Groton	Cabot
Dummerstown	Bethel
Hardwick	Calais

The stone is also manufactured in other places away from these producing centers.

* Read before the Vermont State Medical Society Oct. 15, 1926. Received for publication May 16, 1927.

Physicians in these localities have opportunities to observe the effects of the industry on granite workers. Moreover, as there is a tendency for these workers to leave their trades and go to the farm when they are failing in health, it becomes possible for a number of physicians outside of the granite centers to observe cases of silicosis.

Past Studies of Silicosis

It is regrettable that textbooks on medicine give so little attention to the condition known as pneumonokoniosis. The average textbook states that it is due to inhalation of dust, but makes no great distinction as to the various kinds of dusts and their effects, and fails to outline a diagnostic standard for it. In the granite industry, we are concerned with the effects of a dust which contains a high percentage of free silica, and the condition which the workers inevitably develop is known as silicosis in order to distinguish it from other pneumonokonioses, such as anthracosis of the coal miners and siderosis of the iron workers.

Dr. A. J. Lanza (2) (3) of the United States Public Health Service published, in 1917, descriptions of this condition as he observed it among the zinc miners in southwestern Missouri. These workers mined zinc ores from flint rocks and were exposed to a dust which was largely composed of silica.

Dr. H. R. M. Landis and his associates in the Henry Phipps Institute, University of Pennsylvania, have studied silicosis among workers in the pottery industry and various other dusty trades (4).

Dr. L. U. Gardner (5), Pathologist and Director of the Saranac Lake Laboratory for the Study of Tuberculosis, and his co-workers have added much to our knowledge of the pathology of silicosis by their animal experimentation.

The United States Public Health Service has completed an extensive study of silicosis and tuberculosis in Barre, but the report has not yet been published.

The British are pioneers in modern research in silicosis. Their principal work has been done among the gold miners in British South Africa (6).

The conclusions of these and other investigators seem to be that dusts of high free silica content, when inhaled, produce certain changes in the pulmonary tissues which strongly predispose the workers to pulmonary tuberculosis.

Etiology of Silicosis

The etiology of the disease is the inhalation of dust containing free silica, or quartz. By chemical analysis granite is usually stated to contain approximately 70 per cent. of silica. This figure, however, must include certain of the silicates as well, inasmuch as there is a lesser amount of quartz (free silica) present. The United States Geological Survey (7) states that "dark Barre" granite contains by petrographic analysis 26.578 per cent. of quartz.

The following are quotations from authorities relative to the cause of silicosis.

Britton (8) says: "While there are a number of dusts which do more or less harm, silica is the only one which has been found to be a serious occupational hazard."

As to etiology, Collis (9) states: "Further consideration, however, has shown that whenever dust-phthisis is present, one special form of dust is also present, viz.: dust of crystalline silica."

Along this line, Kettle (10) adds: "There is general agreement that the prolonged inhalation of dusts containing silica is dangerous to life: first, because of the chronic fibrotic changes brought about in the lungs by the inhaled dust, and, secondly, because of the abnormal susceptibility to pulmonary phthisis which is apparent in silicotic individuals."

A striking difference in the effects produced by the inhalation of silica dusts and dusts containing silicon in other forms is seen in comparison of the effects of dusts inhaled by workers in granite and workers in carborundum, or silicon carbide. It has not yet been demonstrated that workers in the carborundum industry develop silicosis. The following quotation summarizes the results of Gardner's (11) experiments with regard to the effects of the inhalation of carborundum dust on guinea-pigs: "Prolonged daily exposures finally cause an oedematous condition in the bronchi and bronchioles which, however, rapidly subsides when the irritation is discontinued. The reaction of the normal lung to excessive quantities of this irritant is surprisingly insignificant. A true fibrosis in the parenchyma of the lung has never been observed. . . . ."

The chemical state of the silica seems to be the main factor in its harmfulness. Among our patients in Barre we see the results of prolonged exposure to granite dust. It would be marvelous, indeed, if persons could work in an atmosphere so highly polluted with a harmful dust and not suffer from the effects of it. It is true that some persons are more susceptible to its effects than others, owing, perhaps, to the efficiency of the upper respiratory tract as a dust arrester. Race, however, does not seem to be a factor, for we have a wide variety of nationalities in Barre and all alike seem to be affected.

Atmospheric Pollution of Granite Plants

The extent of atmospheric pollution in five granite cutting plants in Barre which are considered representative of the industry as a whole is indicated as follows (12): "The average dustiness of five plants investigated as representative of different types, was 2397 particles per cc. weighing 72.0 mg. to the cu.m. In other words, the granite workers inhale nearly 2,000,000 microscopic dust particles with each breath. Petrographic analysis of the air-floated dust shows it to average about the same in mineralogic composition as the granite itself."

Considered in connection with the chemical nature of granite dust previously given, this statement seems to set forth the exact nature of the dust which the granite worker breathes into his lungs.

Tuberculosis Death Rate in Vermont

According to the findings of Frederick L. Hoffman (13) in his survey made in Barre and other parts of Vermont, the death rate from pulmonary tuberculosis among granite cutters in Vermont in 1917 was 1,095.5 per hundred thousand as compared with a rate of only

96.4 per hundred thousand among the total adult population (20 years of age and over) in the state in the same year. These conclusions were reached after a comprehensive study of the death records of the state.

Simple Silicosis

Diagnosis

In making a diagnosis of silicosis, the history of the patient is very important. It should show the number of years of exposure to dust and the specific nature of the worker's trade. The history of respiratory diseases which the patient has had is also important as it may indicate what complications may be expected in the course of the silicosis.

The history, then, should include occupation; length of time exposed; social conditions; respiratory diseases; and general information.

In considering the clinical manifestations of silicosis, information relative to the following should be elicited: dyspnea, onset and duration; cough; expectoration; and pleurisy pains.

Silicotic patients are loath to give an accurate history of anything referable to their chest conditions as they have a profound fear of tuberculosis. For example, many times they state that they are not dyspneic when it is very evident that they are.

The physical examination should include a thorough examination of the chest. Chest movements and measurements should be carefully studied. There seems to be an early limitation of expansion and the type of breathing becomes more abdominal as the condition progresses. In the later stages, when dyspnea is more in evidence, the accessory muscles of respiration are brought prominently into use.

There is a general impairment of resonance over the chest; tactile fremitus is diminished and in severe cases it may be absent.

One of the important points in making a diagnosis of silicosis is the change in breath sounds. This is quite constant and can be noted early. There is a general diminution in the respiratory sound throughout and at times it is almost inaudible over portions of the chest. In later stages, when greater respiratory effort is being made, there may be a peculiar whiffing sound. Dr. Lanza's findings among the zinc miners (2) seem to coincide with these statements; he says, "The most constant sign was weakened breath sounds." He adds further, "Diminished vocal resonance was not infrequently noticed over the areas of weakened breath sounds."

Râles are absent in these cases unless there is a complicating condition.

The greatest aid in making a diagnosis of silicosis is an X-ray picture of the chest. The fibrosis incident to silicosis will be shown usually well diffused over both pulmonary fields.

In addition to the examination of the chest there should be a general physical examination, as it will be found that there is a lowered blood pressure and a chronic rhinopharyngitis. These signs are not pathognomonic but are points in making the diagnosis. The vital capacity should be taken as it will be found lessened in direct proportion to the number of years of exposure and to the lowered blood pressure.

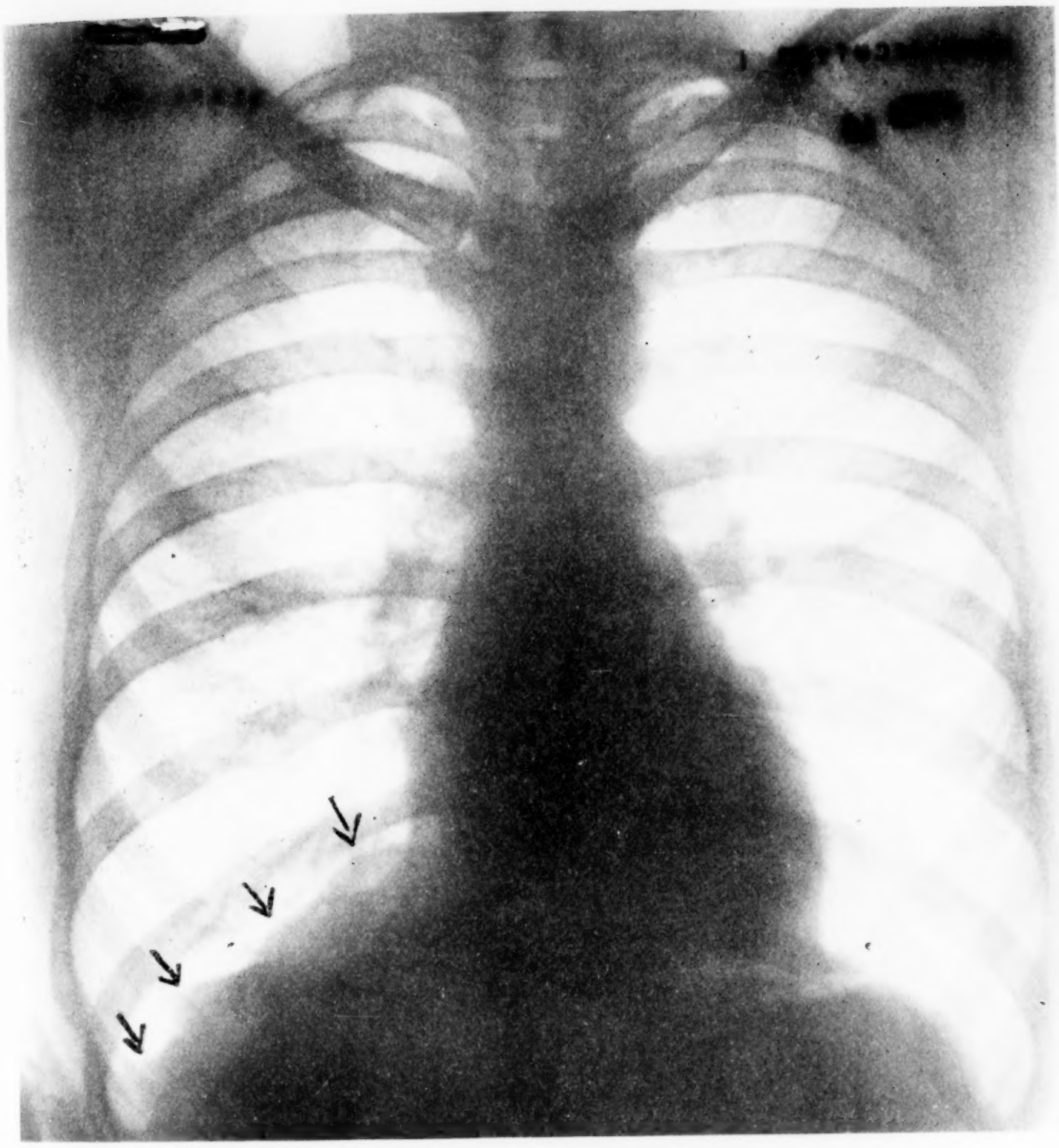

FIG. 1.—Case 1. Showing a typical case of early silicosis. Note the irregularities of the diaphragm on the right and the linear markings in both pulmonary fields.

CASE 1.—Male, Scotch, aged 34 years, married.

This patient had been a granite cutter for fourteen years. His family history was negative. His personal history showed that he had had appendicitis three years previous to this examination and had made a good recovery after operation. His health generally was very good; his habits were good.

Physical examination showed that his teeth were in poor condition, that his systolic blood pressure was slightly lowered, and that his vital capacity was diminished by 1,200 c.c. His chest expansion was poor and there was impaired resonance throughout. Tactile fremitus was normal. Breath sounds were feeble throughout both lungs.

This case was diagnosed as early silicosis (see Fig. 1).

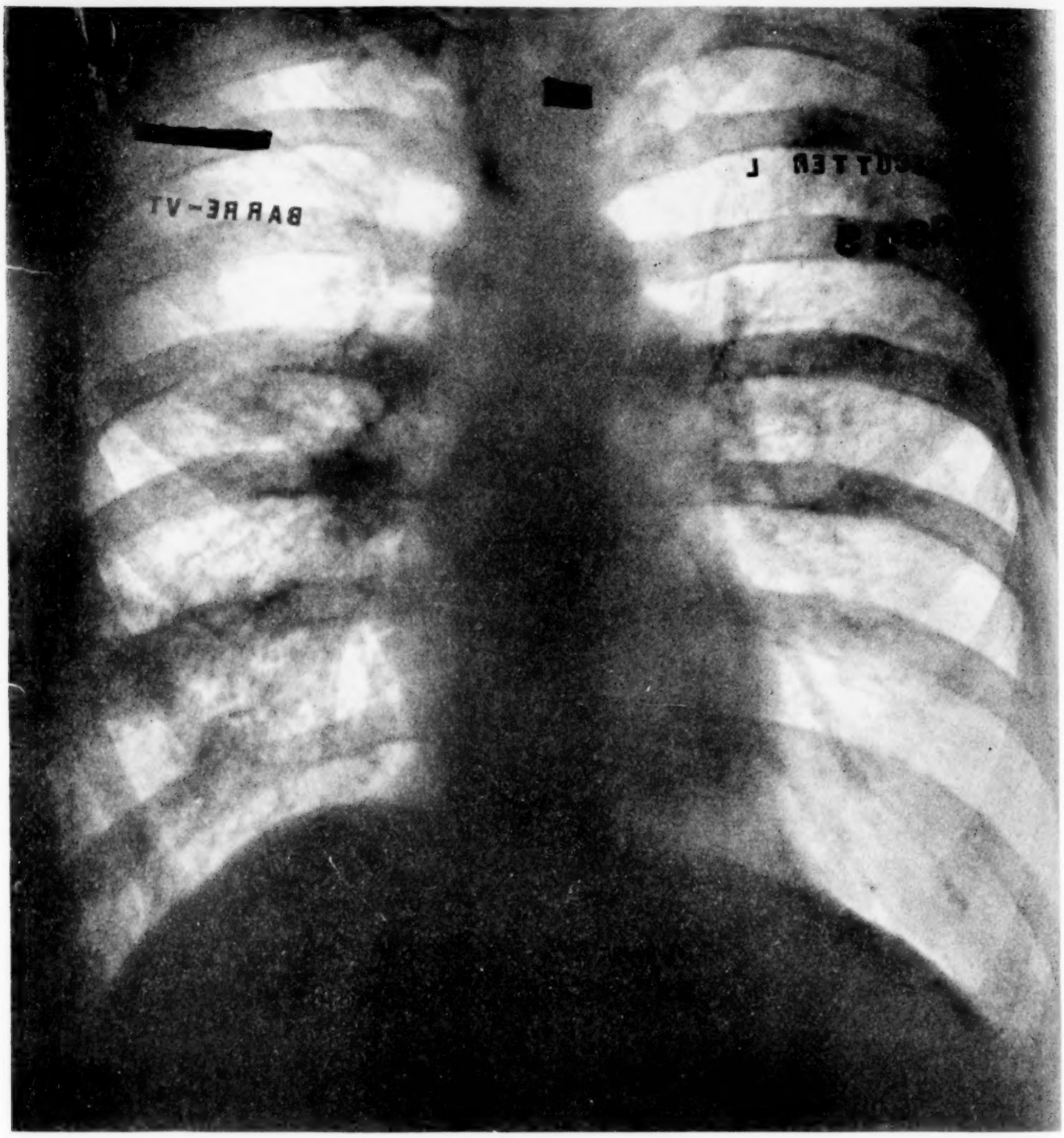

FIG. 2.—Case 2. Showing a more advanced stage of silicosis than that shown in Figure 1. Note the predominance of shadows on the right and in the lower portions of both lungs.

CASE 2.—Male, Scotch, aged 39 years, married.

This patient had been a granite cutter for twenty years, and a sand blaster for two years. His family history was negative. His personal history indicated that he had had excellent health. His habits have been good.

Physical examination of the chest showed evidence of silicosis. Otherwise the patient's physical condition was good. He works regularly and loses no time from illness.

This is a case of silicosis at a more advanced stage (see Fig. 2) than that shown in Figure 1.

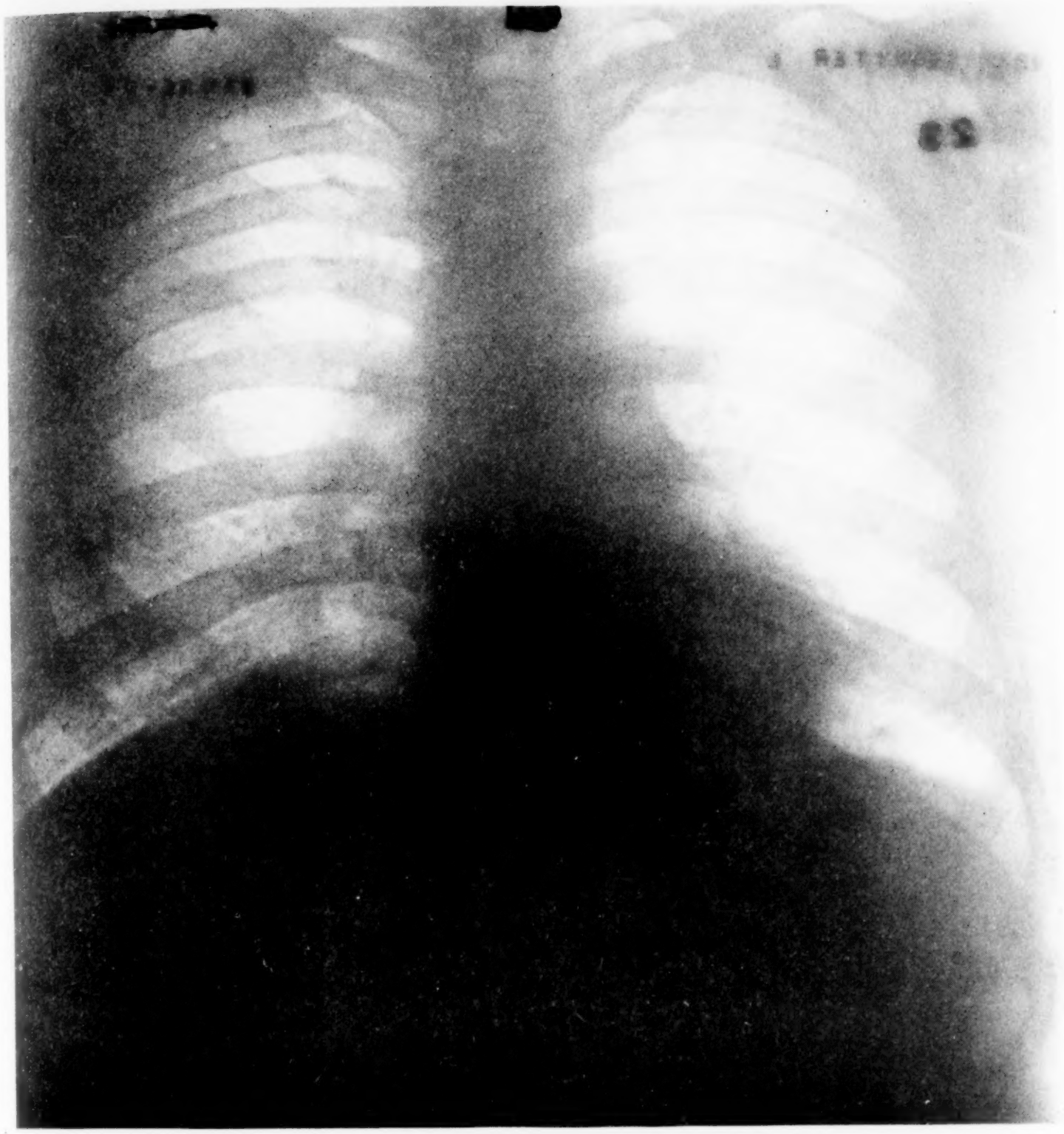

FIG. 3.—Case 3. Showing a more diffuse silicosis than that shown in Figure 2. Note the predominance of markings in the lower portion of the right lung.

CASE 3.—Male, Scandinavian, aged 42 years, married.

This patient had been a granite cutter for twenty-three years. His father died of cancer at the age of 50; his mother died at the age of 52, cause unknown. The patient's personal history showed that he had had pneumonia in the winter of 1924 to 1925 and was ill for three months. Otherwise his health generally has been good, and he works regularly.

Physical examination was negative except that the chest showed evidence of a general silicosis (see Fig. 3). Vital capacity was diminished by 3,000 c.c.

The points in diagnosis of silicosis may be summarized as follows: history, dyspnea, diminished chest expansion, diminished resonance generally, diminished tactile fremitus, change in breath sounds, absence of râles, absence of toxemia, characteristic X-ray findings, lowered blood pressure, and lowered vital capacity.

The histories in Cases 1, 2, and 3 are interesting; the roentgenograms (Figs. 1, 2, and 3) show the fibrosis incident to simple silicosis.

Pathology

The pathology of silicosis may be summarized as massive fibrosis of the lungs. I have seen the fibrous induration so marked that the lungs would not collapse when removed from the chest at autopsy, and the imprint of the ribs remained on them. The dense pleural adhesions are striking and render it a difficult task to remove the lungs from the thoracic cavity. I saw a case where the patient had been exposed to granite dust less than three years and there were numerous pleural adhesions present. In this case there was no history of any respiratory disease other than colds. The lymph glands around the hilum were very firm in these cases and, when cut, a grating sound was produced as though a small bag of wet sand were cut through.

Complications of Silicosis

The foregoing have been the findings of silicosis uncomplicated; when complications occur, there are further changes which are quite characteristic.

Chronic bronchitis is not a very frequent complication although it does occur. There is nothing unusual about its manifestation. Silicotic patients are prone to attribute any chest condition to bronchitis even when their illness is far advanced with tuberculosis; they usually insist that they have "bronchial trouble."

There may be an excess of pneumonia among these patients but it is apparently slight. The severity of the pneumonia, here as elsewhere, depends on the organism.

Silicosis with Tuberculosis

The most common complication is tuberculosis. Again, Dr. Lanza's (3) cases in southwestern Missouri seem to parallel ours here in Barre. He states: "A tuberculous infection may take place at any stage of miners' consumption, and it is the opinion of the writer that practically no cases die without its being present."

As the years of exposure to granite dust increase, the prevalence of tuberculosis also increases. It occurs usually after the age of 45, although it may occur at any time.

Diagnosis

With the onset of tuberculosis, the clinical picture changes rapidly. There is now a bacterial invasion, destruction of tissue, and toxemia. In addition to the symptoms present in silicosis there will usually be found the following: increase in dyspnea, pleurisy pains, fatigue, cough, expectoration, fever, night sweats, hemoptysis or pulmonary hemorrhages, loss of weight and strength, and any other symptoms in common with tuberculosis.

Patients having silicosis complicated with tuberculosis are particularly prone to have pulmonary hemorrhages

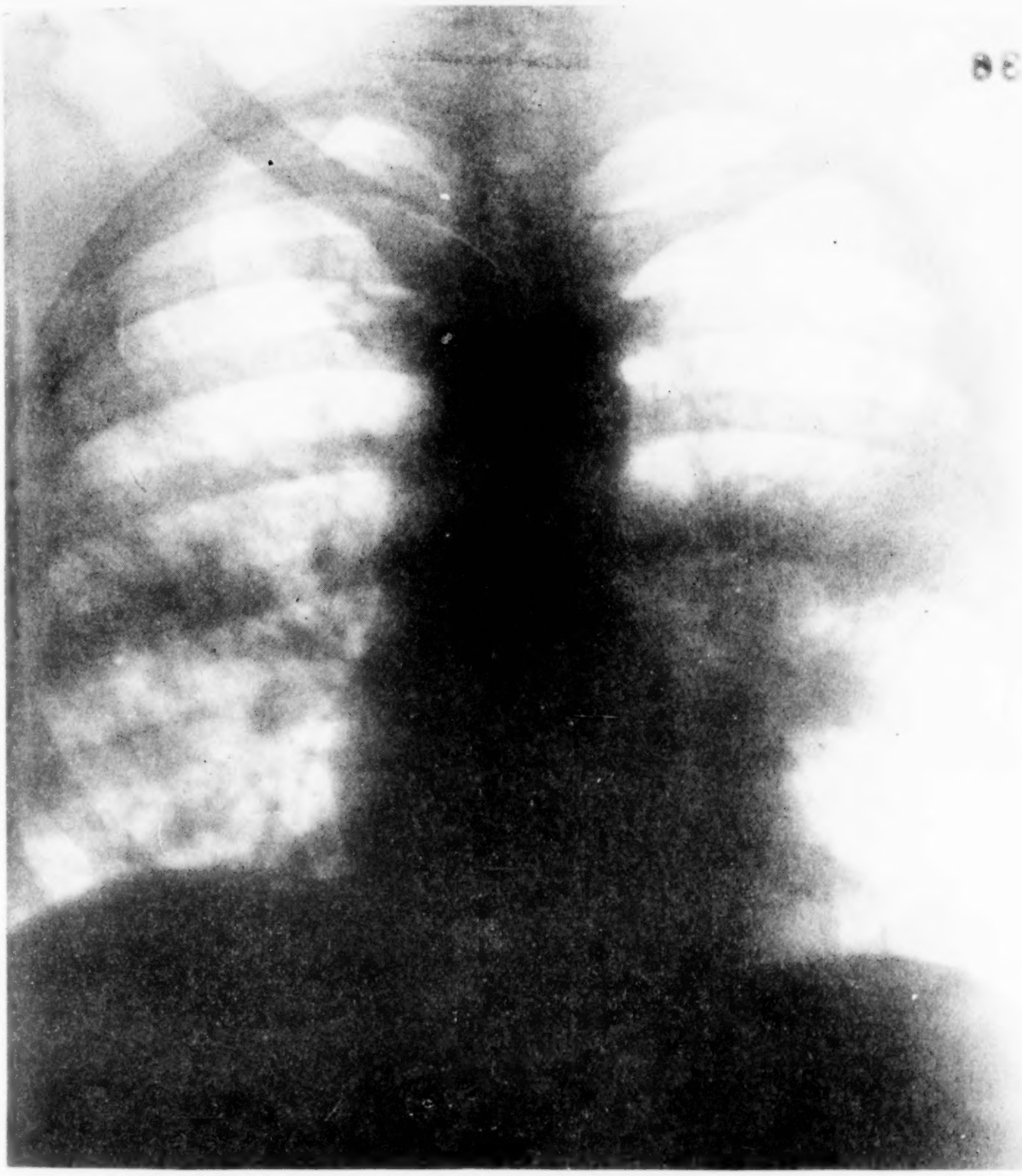

FIG. 4.—Case 4. Showing a case of silicosis complicated with tuberculosis. Note that there is a tendency for the shadows to become more confluent. This is more pronounced in Figures 5 to 8.

CASE 4.—Male, Scotch, aged 50 years, married.

This patient was a granite cutter for thirty years and a sand blaster and letterer for five years. His father died of apoplexy at the age of 71; his mother died of bronchitis at the age of 77. His past history showed that his health generally had been good.

At the time of this examination the patient complained of a severe cough, expectoration, pains in the chest, dyspnea, fatigue, and loss of weight. His chest showed evidence of tuberculosis in both lungs and a general silicosis. Sputum contained tubercle bacilli.

This is a case of silicosis complicated with tuberculosis (see Fig. 4). The patient died several months after the X-ray picture was made; he was very emaciated and had the usual symptoms incident to advanced pulmonary tuberculosis.

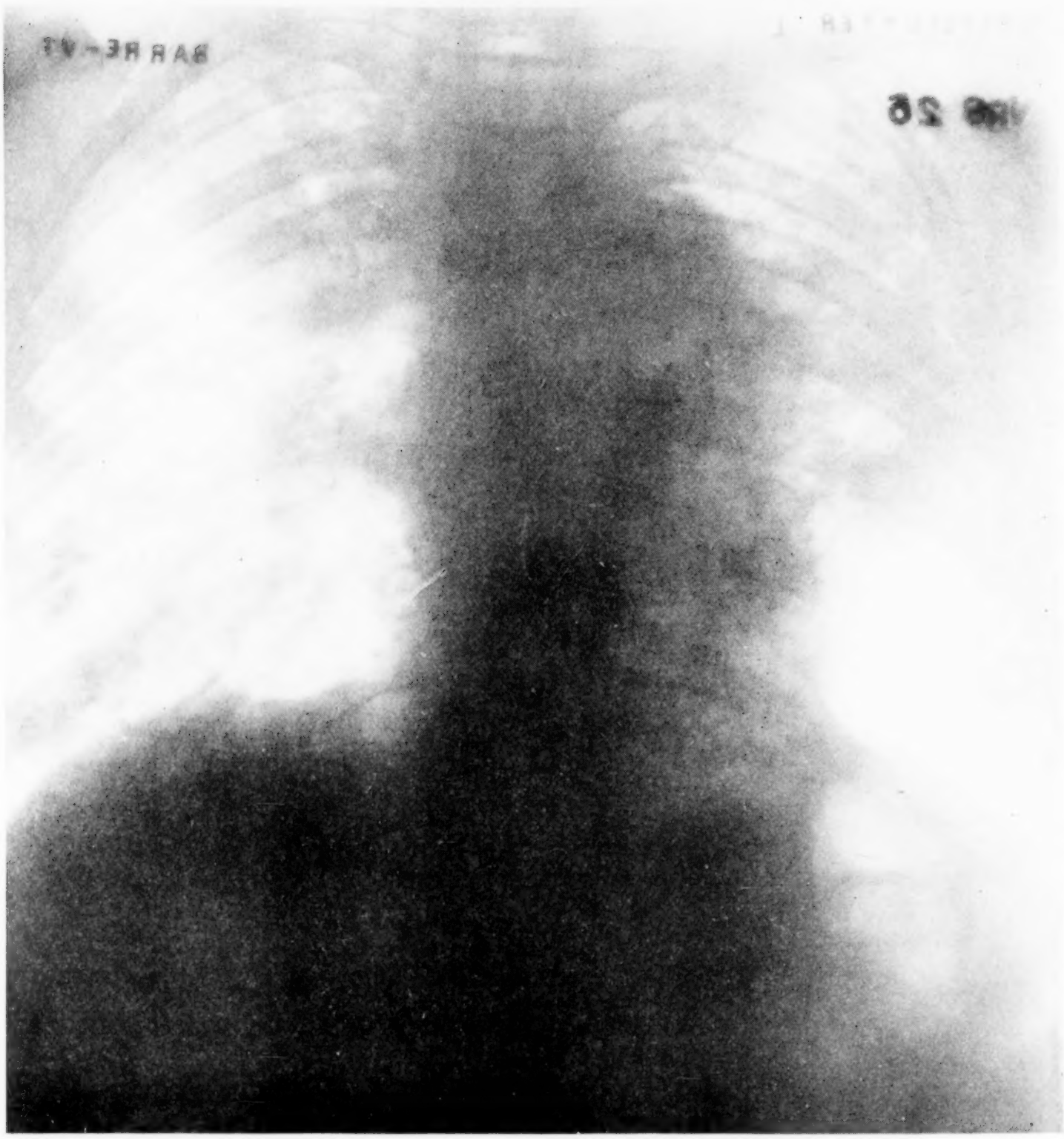

FIG. 5.—Case 5. Showing a case of silicosis complicated with tuberculosis. Note the diaphragmatic adhesions on the right.

CASE 5.—Male, Scotch, aged 56 years, married.

The patient was a granite cutter for twenty-four years, foreman in a granite plant for twelve years, and superintendent of a granite plant for six years. He had not cut granite for eighteen years, but had been in a dusty atmosphere. His father died of apoplexy at the age of 57; his mother died of cancer at the age of 57. He gave a history of pneumonia three years previous to this examination and of influenza in 1919. He has had severe dyspnea for several years.

At the time of this examination the patient complained of dyspnea, cough, expectoration, loss of weight and strength, and pains in the chest.

Physical examination showed a small tuberculous ulcer in the nose, and chronic pharyngitis. Chest expansion was almost nil. There was evidence of an advanced tuberculosis and silicosis. Sputum contained tubercle bacilli.

This case was diagnosed as silicosis complicated by tuberculosis (see Fig. 5). The patient died two months and ten days after he stopped working (not quite a month after this examination).

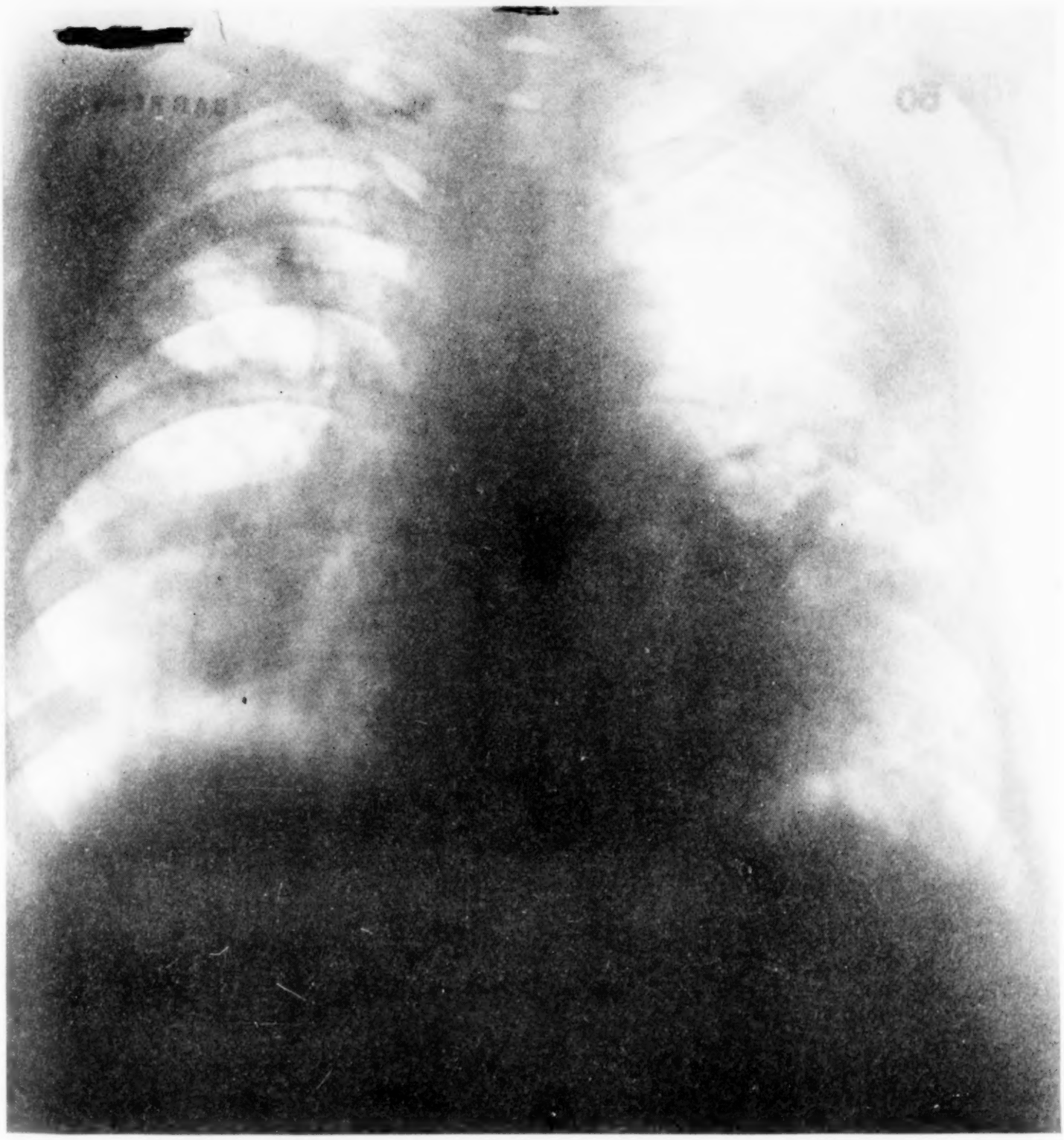

FIG. 6.—Case 6. Showing a case of silicosis complicated with tuberculosis. Note that the tuberculous lesions are principally in the lower portions of the lungs, as is quite common in such cases.

CASE 6.—Male, Scotch, aged 63 years, married.

This patient has cut granite for fifty years, perhaps half of the time with pneumatic tools. His father died of septicemia at the age of 69; his mother died of senility (?) at the age of 68. The patient had typhoid fever at the age of 30; otherwise his health generally had been good. His present illness began with severe pains in the chest, with cough and expectoration, and loss of weight and strength. These symptoms have become more marked with the progress of the disease. Chest examination showed evidence of an advanced tuberculosis and a general silicosis.

This case is interesting as it represents silicosis complicated by tuberculosis (see Fig. 6).

FIG. 7.—Case 7. Showing a case of silicosis complicated with tuberculosis.

CASE 7.—Male, Italian, aged 57 years, married.

This patient had been a marble cutter for seven years prior to coming to the United States. He has been a granite cutter for thirty-four years. His father died of pneumonia at the age of 73; his mother died of senility at the age of 84. His past history showed that his health generally had been good and that his habits were good. Three years previous to this examination he had had an operation for glaucoma, from which he had made a good recovery. His present illness began about one year ago and at present he complains of cough, expectoration, dyspnea, nervousness, and loss of weight.

Physical examination revealed evidence of a tuberculous lesion in the left lung and a general silicosis in both lungs. Sputum contained tubercle bacilli.

Figure 7 shows the X-ray picture of this case.

FIG. 8.—Case 8. Showing a case of advanced tuberculosis with silicosis. Note the cavity in the left upper lobe; also the diaphragmatic adhesions on both sides.

CASE 8.—Male, English, aged 59 years, married.

This patient was a farmer until he was 20 years of age. He has been a granite cutter for thirty-eight years. His past history indicated that his health generally was very good, and his habits were good.

Physical examination showed evidence of pulmonary tuberculosis and silicosis. The sputum contained tubercle bacilli.

The X-ray picture is shown in Figure 8. This case presents the picture usually seen in a case of advanced tuberculosis with silicosis.

throughout the course of the disease. A number of patients may have this as a first noticeable symptom, and many of them die of hemorrhages from the lungs. Several have died on the street, and one died on my lawn attempting to reach the office for aid.

Physical examination will not reveal the same findings as in a case of tuberculosis uncomplicated by silicosis, because of the changes in the pulmonary tissues prior to the onset of tuberculosis. The findings are not always constant but it is usually an easy matter to discover enough to warrant a positive diagnosis. In addition to the findings in a case of silicosis, there will usually be the following: localized areas of dulness, further changes in breath sounds, presence of râles, presence of tubercle bacilli in the sputum, and characteristic X-ray findings.

Besides the general impairment of resonance incident to the silicosis, now areas of dulness will be found. The changes in breath sounds are not so marked as would be expected because of the preexisting pathology. In the more advanced cases, there may be evidence of cavitation. The presence of localized râles which persist after coughing is as constant as in a case of ordinary tuberculosis.

Laboratory findings will usually show the presence of tubercle bacilli in the sputum early in the disease. A negative sputum does not indicate that the patient is not tuberculous. Repeated analyses will usually show that bacilli are being liberated in the sputum. I think we, as general practitioners, do not make a sufficient number of tests in patients supposed to have a negative sputum.

Five cases of silicosis with tuberculosis complicating had histories as given with the roentgenograms (Figs. 4, 5, 6, 7, and 8).

TABLE 1.—COMPARISON OF DURATION OF EXPOSURE IN CASES OF SIMPLE SILICOSIS AND IN CASES OF SILICOSIS WITH TUBERCULOSIS

CASE NO.	AGE	DURATION OF EXPOSURE TO DUST	DIAGNOSIS
		yrs.	
1	34	14	Silicosis.
2	39	23	
3	42	23	
4	50	35	Silicosis with tuberculosis.
5	56	42	
6	63	50	
7	57	34	
8	59	38	

In Table 1 is shown the effect of the long exposure to dust in the five cases of silicosis complicated with tuberculosis as compared with the three cases of simple silicosis cited previously.

Course of the Disease

The course of the disease is almost invariably rapid and the prognosis is grave. These patients do not have periods where the disease seems to be at a standstill or retrogressing as in cases of ordinary pulmonary tuberculosis.

Tuberculous complications may occur but apparently they are much less frequent than in other cases of pulmonary tuberculosis, owing to the rapid course of the disease.

Pathology

There is usually rapid destruction of tissue, and caseation and excavation are much in evidence. An excess of fibrosis and dense pleural adhesions incident to the silicosis are already evident.

I saw one case at autopsy where the whole lung was completely excavated to the pleura and from the apex to the hilum. The patient had profuse pulmonary hemorrhages before death, as there was complete destruction of the smaller blood vessels and extensive erosion and thromboses of the larger ones.

Fallacious Ideas with Regard to Silicosis and Tuberculosis

There has been much confusion locally over the condition which the granite cutters develop and equally as much confusion as to whether or not "granite cutters' consumption" is contagious. This confusion is apparently due to the fact that silicosis, which is the first pathologic condition that the workers develop, is not differentiated from the tuberculosis which they develop at a later period as a complication. Silicosis, being a nonbacterial condition, is not transmissible; but when it is complicated with tuberculosis, and the patient is liberating tubercle bacilli in the sputum (as most of them do), the case is as great a menace to others as is any other case of tuberculosis—indeed, it is perhaps a greater menace owing to the existing fallacy that the condition is not contagious, and to the fact that the necessary precautions are, therefore, usually omitted.

Tuberculosis in Families of Granite Cutters

We see in Barre a number of cases of tuberculosis among the families of granite cutters, and there seems to be an undue prevalence of tuberculous meningitis in families where there are small children. The proportion of tuberculosis among the families is perhaps less than that among the general population outside of the granite industry, because the average granite cutter develops pulmonary tuberculosis when he is past 45 years of age and at this time his children are older and less susceptible to infection. Moreover, they are usually in school and there is not the close contact which prevails in earlier life. Persons outside of the granite industry who have pulmonary tuberculosis usually develop the disease in early adult life when their children are small and the personal contact is greater. The granite cutters are above the average industrial worker intellectually, and they make good wages and live well. They usually have very comfortable homes. These are factors which should cause a low incidence of tuberculosis not only among themselves but also among members of their families. Another factor is that the rapid progress of the disease among granite cutters renders their period of infectivity much shorter than it is in the average case of tuberculosis.

Summary and Conclusions

Vermont produces excellent granite and in great quantities. The future of this industry, which is one of the largest in the state, depends on the health of its workers.

Physicians of Vermont should be vitally interested in silicosis and its prevention, not only for the sake of the granite industry but as a part of the public health program of the state.

Granite workers develop silicosis after long exposure to granite dust and in time almost invariably develop tuberculosis as a complication.

In making a diagnosis of silicosis there are certain constant signs which should be looked for. Care should be taken to differentiate simple silicosis from silicosis complicated by tuberculosis. Silicosis when complicated by tuberculosis runs a rapid course and the prognosis is always grave.

Silicosis is preventable and steps should be taken to protect the workers by installing adequate exhaust and ventilating systems. The present incidence of silicosis and tuberculosis among granite workers is sufficient evidence that the exhaust and ventilating systems in use during their industrial life were inadequate.

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METAL FUME FEVER: IV. THRESHOLD DOSES OF ZINC OXIDE, PREVENTIVE MEASURES, AND THE CHRONIC EFFECTS OF REPEATED EXPOSURES*

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INTRODUCTION

FINELY divided metal fume products, such as zinc oxide, when breathed in sufficient quantity, cause a systemic reaction known as metal fume fever (1). The maximum febrile reaction generally occurs within ten or twelve hours after inhalation of the fume and is accompanied by a pronounced leukocytosis and a reduction in vital capacity. About twenty-four hours after the inhalation, body temperature and vital capacity return to normal, but leukocytosis persists for some twelve hours longer. If a second inhalation follows the first during this final period of leukocytosis, there is evidence of an acquired resistance (2) which prevents the occurrence of a severe febrile reaction."

It was formerly thought that only the heavy metals (3) would produce this fume fever. We have recently found, however, that freshly generated magnesium oxide (4)—a product of one of the lightest metals—produces a fever analogous to that caused by the heavy metals.

"Metal fumes which produce fever are most commonly met with in industries where metallic zinc is heated in an oxidizing atmosphere to a temperature near its boiling point (930°C.). This occurs, for example, in the founding of brass (5) and, to a lesser extent, in processes like the oxyacetylene welding of galvanized iron" (6) (7, p. 283).

"In plants where zinc ores are smelted or zinc products manufactured, zinc oxide fume in the air at large means a measurable loss of zinc and efficient operation demands the reduction of this loss to a minimum." It is not surprising, therefore, that Thomson (8) found low concentrations of zinc oxide in the factory air of a large metallurgic establishment—the concentrations to which the men were exposed being, in general, below 50 mg. of zinc per cubic meter. In this plant instances of fume fever were rare. In a large, modern, well-equipped brass foundry, on the other hand, he

* Received for publication May 13, 1927.

found that the concentration of zinc in the air that the workmen breathed ranged from 2 to 1,110 mg. per cubic meter. Out of nineteen samples taken on three different days in representative atmospheres, seven were well above 50 mg. per cubic meter. Here the fume fever was often experienced. These two examples are, we believe, representative of present day conditions in the United States. In the zinc industry, the very nature of the processes demands the captation of the fume; in the founding of brass, the fume is considered a nuisance, but its captation is not a question, directly, of economy or plant efficiency.

Except for the limited data published by Lehmann (9), Arnstein (10), and Burstein (11) on concentrations which produce fever, there are apparently no figures from which one can estimate concentrations that may safely be permitted in industry. The purpose of this paper is to supply such data and to discuss how the fever can best be prevented.

Experimental Procedure

Generation and Measurement of Zinc Oxide Fume

In the experiments described here, we have used zinc[1] of the following composition:[2]

	%
Fe	0.0100
As	0.0002
Sb	0.0001
Al	0.0001
Sn	0.0010
Bi	0.0001
Cu	0.0002
S	0.0001
Pb	0.0620
Cd	0.0020
Zn (difference)	99.9242

Pieces of this zinc were placed in a double-lined alundum muffle furnace, electrically heated, and brought to a temperature high enough to cause a slight evolution of zinc oxide. A gentle stream of oxygen was then blown into one end of the muffle across the molten zinc and a copious evolution of fumes escaped from the other end into a 1,600 cubic foot (45 cubic meter) gas cabinet (12). The fumes were allowed to diffuse in the cabinet until successive readings by Tyndallmeter (13) showed that the suspension was settling out uniformly. When this point was reached—it required about twenty minutes—samples of the suspension were taken by electric precipitator (14). In experiments of several hours' duration, we purposely did not use fans because, as we have shown elsewhere (15), turbulent air currents accelerate the clearing up of freshly generated suspensions like zinc oxide. In experiments of short duration, however, fans were sometimes used in order to reduce the time required for the clouds to become diffused uniformly.

Settling Curves

Suspensions made in this manner always settle out, and the rapidity of their settling must be considered in

[1] Furnished by the New Jersey Zinc Company, Palmerton, Pa.

[2] In practice it is found that zinc oxide fume contains impurities like cadmium oxide, copper, and copper oxide in amounts which are governed by the partial pressures of the elements of these compounds in the melt (usually brass) and their respective heats of oxidation (5).

order to know the concentration at the time the inhalation experiment is performed. In Figure 1 we have plotted time as abscissas against Tyndallmeter readings and concentrations as ordinates. The data for the curve were obtained by sampling by Tyndallmeter and precipitator, the one serving as a check on the other. As the result of plotting many of these curves, we find that three or four precipitator samples and about six Tyndallmeter readings suffice to locate a six-hour settling curve such as that shown in Figure 1.

It will be seen from this curve that, during a twenty-minute inhalation at high concentrations (10 foot candles), the concentration will fall off some 10 per cent. We assume that the concentration actually breathed by the subject during such an exposure is represented by a point midway between the concentration at the beginning and that at the end of the exposure.

The three points indicated on this curve as "analyses (elec. pptr.)" were obtained by drawing measured volumes of the zinc oxide suspensions through an electric precipitator which collected the zinc oxide on celluloid foils (14). To the material on the foil was added the trace[3] on the precipitating electrode—a piece of stiff steel wire, plated with gold. The precipitate was dissolved in 0.1 N sulphuric acid and the zinc was determined either by titration or by turbidity. In both cases potassium ferrocyanide and Fairhall's method (16) were used. In every instance, results are given in terms of zinc and not of zinc oxide.

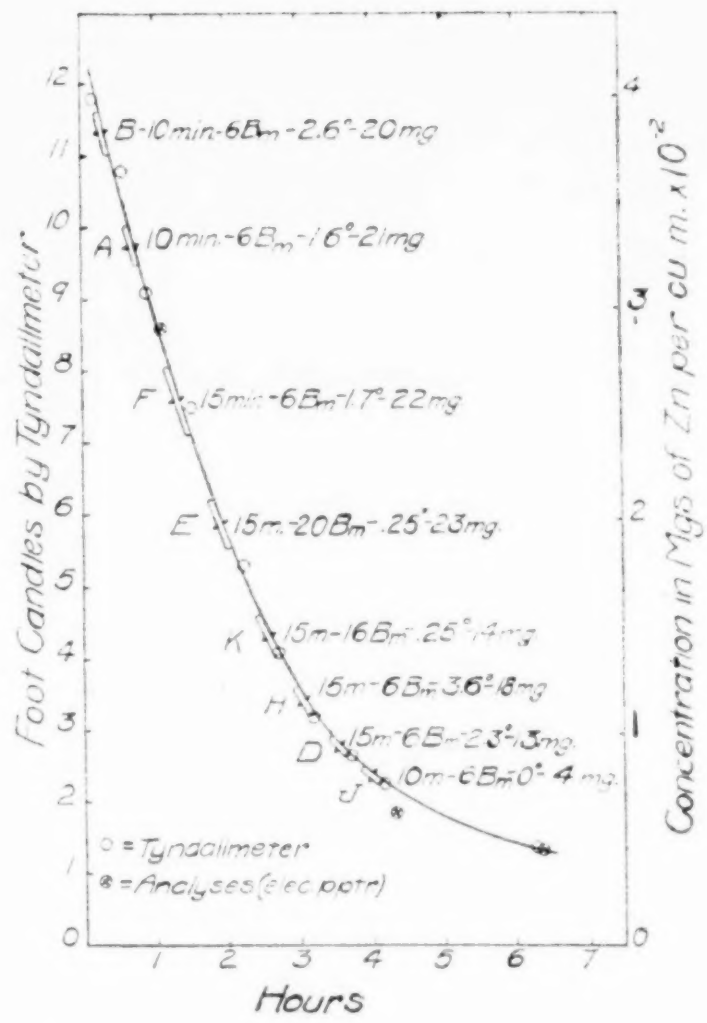

FIG. 1.—Inhalation experiments plotted on a typical settling curve for freshly generated zinc oxide fume. Brackets on the curve indicate the actual time and duration of each inhalation experiment. Example: B–10 min.–6Bm–2.6°–20 mg. means that subject B (see Table 1) inhaled zinc oxide for ten minutes, took 6 breaths per minute, his temperature ultimately rose 2.6°F. above the normal, and he inhaled a total of 20 mg. of zinc.

Inhalation Method

Figure 2 shows the set-up used in most of the inhalations. The subject wears the facepiece of a Kops type gas mask, inspires through a rubber flap valve into the mask, and expires through another valve into an electric precipitator and thence to a spirometer. The precipitator collects the fume expired and the spirometer measures the volume of air breathed.

The use of a precipitator in experi-

[3] About 2 or 3 per cent. of the precipitate on the celluloid foil.

ments of this type was first suggested by Baumberger (17). His method was improved by Sayers, Fieldner, and their associates (18) and was modified further by us, as illustrated in Figure 2.

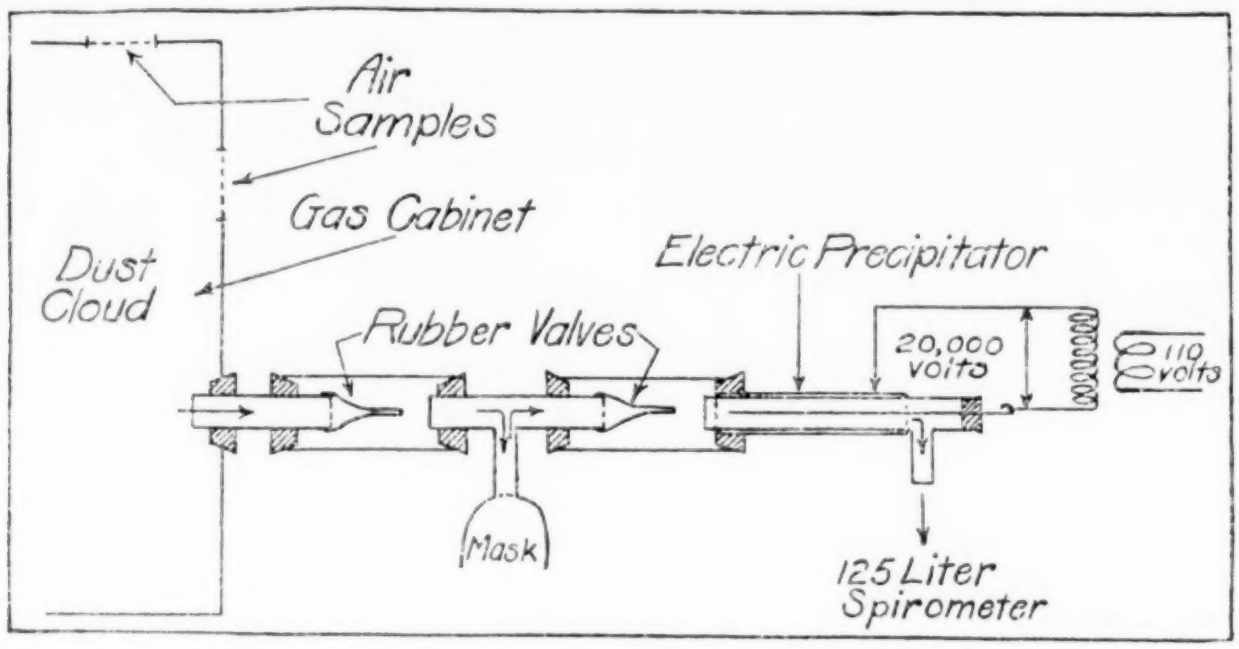

FIG. 2.—Apparatus used for determining the inhalation, retention, and expiration of zinc oxide fume.

The losses of suspension through impingement and settling within the portion of the apparatus leading from the gas cabinet to the precipitator are considerable. Losses between the cabinet and the mask must be subtracted from the concentration in the cabinet, and losses on the outlet side of the face mask must be added to the suspension caught in the precipitator. These losses are always significant and cannot be ignored, even in suspensions of very low concentration.

In several experiments, where the purpose was simply to produce the fever with known concentrations of zinc oxide and not to determine the amount of fume retained or expired, the subjects entered the cabinet and breathed the fume directly, noting their own breathing rates and the lengths of their exposures. From the inhalation experiments on these same subjects where the mask was worn and from numerous experiments in pure air, we were able to estimate, with reasonable assurance, the minute-volumes breathed in the cabinet. Knowing the concentration from the settling curve, we then calculated the amount of fume actually inspired.

In Table 1 we have given the data from twenty-seven experiments. In twenty-one of these the subjects wore the face mask; in the other six (indicated by footnote 2), the subjects remained in the cabinet but did not wear masks.

As will be seen later, we assume that one-half the fume inhaled is retained and one-half is expired. Although this ratio is not constant, for the purposes of the present paper the assumption is justifiable. In a future paper we shall give these relations in more precise form.

Measurement of Severity of Reaction

As a measure of the severity of the reaction, we have used the rise in oral temperature taken over periods of

three minutes or more. Increases of 0.25°F. in experiments 20 and 27, Table 1, are arbitrarily assigned in two cases where both subjects reported conditions of malaise which were well defined but which actually produced no significant rise in temperature. In all other cases, temperature increases are those actually measured.

The ten subjects from whom these data were secured were engaged in laboratory work in the Department of Ventilation and Illumination and the Department of Physiology of the Harvard School of Public Health; they were thoroughly familiar with the procedure of taking the data (temperatures, symptoms, etc.) and submitted their reports after each experiment. All the subjects had avoided exposures to zinc dusts and fumes for five days preceding these experiments.

Manner of Breathing and Minute-Volume

A very important factor in one's reaction to metal fume inhalations is the manner of breathing. Unless account is taken of this, a statement of threshold concentrations in terms of length of exposure is misleading.

Slow breathing always produces severer reactions than rapid breathing or breathing at a normal rate, which indicates that the seat of the reaction to the fume particles is in the alveolar spaces and not in the upper respiratory passages. Hence, in order to secure penetration of the fume particles into the alveolar spaces, we have had recourse, in many of our experiments, to abnormally slow, deep breathing. Deep breathing can be induced by (*a*) breathing slowly (6 respirations a minute), (*b*) adding carbon dioxide to the intake air (19), and (*c*) exercising. For experimental purposes, the slow breathing method is the most satisfactory. The average healthy subject can breathe at a minimum rate of about six times a minute without discomfort, and, after a little practice, can give reasonably constant minute-volumes. If we compare the minute-volumes with normal breathing and those with slow breathing (Table 1, Column V), it will be seen that, in most instances, our subjects inhaled appreciably less air when breathing slowly than when breathing at rates of 12 to 18 respirations a minute. This is in accordance with the physiologic expectation and is an entirely normal circumstance.

When a subject inhales dust or fume for experimental purposes, a number of unusual elements enter in, and these elements may, in short exposures, alter the normal minute-volume considerably without the subject's being aware that he is breathing in an unnatural manner. He is conscious that he is under observation, he perhaps is wearing a tight-fitting face mask, and he is inhaling dusty air which may produce tracheal irritation and coughing. Moreover, the experienced subject, who has undergone an attack of the fever as the result of a previous experiment, instinctively tends to reduce his minute-volume in subsequent experiments.

In one of his studies in a brass foundry, Thomson timed the rate at which an experienced caster breathed while skimming off a pot of molten brass prior to pouring. The operation required about two minutes, during

TABLE I.—PROTOCOL OF TWENTY-SEVEN EXPERIMENTAL INHALATIONS OF FRESHLY GENERATED ZINC OXIDE FUME

EXPERIMENT	VITAL CAPACITY	I CONCENTRATION OF ZINC	II EXPOSURE	III RESPIRATIONS[1] PER MINUTE	IV TOTAL AIR BREATHED	V IV ÷ II MINUTE VOLUME	VI TOTAL ZINC INHALED	VII VI ÷ III AVERAGE AMOUNT OF ZINC INHALED PER BREATH	VIII I × II ÷ III $\frac{C \times E}{B}$	IX RISE IN BODY TEMPERATURE	
	l.	*mg./cu. m.*	*min.*		*l.*	*l.*	*mg.*	*mg.*		*°F.*	*°C.*
Subject A, aged 32, M.											
1	6.1	110	10	13	123	12.3	13	0.10	85	0.0	0.0
2		180	22	5	222	10.0	41	0.31	790	4.6	2.6
3		360	20	15	226	11.3	82	0.27	480	1.6	0.9
4		240	10	6	89	8.9	21	0.35	400	1.6	0.9
5		270	8	12	74	9.3	20	0.21	180	0.7	0.4
6		350	15	7	105	7.0	37	0.35	750	4.1	2.3
7		25	40	6	264	6.6	7	0.03	167	0.0	0.0
8		52	20	6	176	8.8	9	0.08	173	0.0	0.0
9		302	17	7	118[2]	6.9[2]	37[2]	0.31	730	2.2	1.2
10		610	11	9	78[2]	7.1[2]	48[2]	0.55	745	3.5	1.9
11		430	8	6	53[2]	6.7[2]	23[2]	0.48	573	2.7	1.5
Subject B, aged 37, M.											
12	4.4	480	10	17	99	9.9	5	0.03	282	0.0	0.0
13		140	21	6	137	6.5	21	0.17	490	0.6	0.3
14		320	21	19	202	9.7	64	0.16	354	0.0	0.0
15		250	10	6	81	8.1	20	0.33	417	2.6	1.4
16		155	21	9	124	5.9	19	0.10	362	0.4	0.2

Subject C, aged 39, M. 17	4.1	590	12	15	126[2]	10.5[2]	74[2]	0.41	472	4.8	2.7
Subject D, aged 29, M. 18 19	4.5	80 302	15 16	6 6	158 125[2]	10.5 7.8[2]	13 39[2]	0.14 0.41	200 805	2.3 2.5	1.3 1.4
Subject E, aged 37, F. 20 21	3.7	150 240	15 18	20 6	150 120	10.0 6.7	23 29	0.08 0.27	113 720	0.25 1.9	0.14 1.1
Subject F, aged 38, M. 22	4.9	190	15	6	134	8.9	22	0.24	475	1.7	0.9
Subject G, aged 35, M. 23 24	4.1[3]	179[4] 150	16 20	10 9	123[2] 137	7.7[2] 6.9	22[2] 21	0.14 0.12	286 333	1.0 1.2	0.6 0.7
Subject H, aged 25, M. 25	5.1	100	15	6	175	11.7	18	0.20	250	3.6	2.0
Subject J, aged 27, F. 26	2.5	67	10	6	55	5.5	4	0.07	110	0.0	0.0
Subject K, aged 27, F. 27	3.4	120	15	16	117	7.8	14	0.06	112	0.25	0.14

[1] Estimated to nearest whole number.
[2] Estimated volume of air and amount of zinc oxide breathed when subjects were in gas cabinet and did not wear masks.
[3] Estimated according to West (20).
[4] Average of concentrations at two periods, five minutes apart.

which the operator breathed deeply eight times a minute. Immediately afterward, he resumed his normal rate of 15 or 16 respirations a minute. This man knew that his work was under observation, but he did not realize that his respiratory rate was being counted. We cite this example to show that our experimental rate of breathing, which seems abnormally slow, is in reality fairly representative of conditions under which intermittent, heavy skilled labor is being carried on in hot atmospheres.

It appears to make little difference whether the subject breathes through the nose or the mouth or through both. Since the particles of our zinc oxide fumes are of the order of 0.3 to 0.4 micron (21), the filtering action of the upper respiratory passages is negligible. Some of the suspension is caught, of course, but the amount is too small to be of physiologic significance. As a defense against fume particles, then, the upper respiratory passages are hopelessly inadequate, no matter what the fume concentration or the rate of breathing may be.

Threshold Dose

On the settling curve in Figure 1, we have indicated the points at which five men, subjects B, A, F, H, and D, and three women, subjects E, K, and J, inhaled freshly generated zinc oxide for periods of ten and fifteen minutes. These data are taken from Table 1, experiments 15, 4, 22, 25, 18, 20, 27, and 26, respectively.

The men breathed at a rate of 6 respirations a minute and all of them had typical attacks of the fever. Two of the women, subjects E and K, breathed normally and had slight reactions or malaise. Although they actually inhaled as much oxide as the male subjects, their reactions were practically negligible. One of the women, subject J, inhaled a subthreshold dose, owing probably as much to her low minute-volume (5.5 liters) as to the low concentration of the fume she inhaled. It will be seen, therefore, that to give dosage simply in terms of milligrams of zinc inhaled per kilo of body weight or per square meter of body surface is insufficient.

There are three variable factors which always affect the extent of the febrile reaction: concentration of zinc oxide, length of exposure, and manner of breathing. We believe that it is justifiable to estimate threshold values in terms of these three variables and from these estimates to arrive at concentrations which, for the average person and the average exposure, produce no reaction.

We may express the relationship between the severity of the reaction and the three variables as follows:

$$T = \int \left(C \times E \times \frac{1}{B}\right) \text{ where}$$

T = rise in body temperature in °F. (Table 1, Column IX),

C = concentration in milligrams of zinc per cubic meter (Table 1, Column I),

E = exposure in minutes (Table 1, Column II), and

B = breaths per minute (Table 1, Column III).

Evaluating the proportional factor, the equation becomes

$$T = \left[\left(C \times E \times \frac{1}{B}\right) - K\right] a, \text{ where}$$

K = the intercept, or threshold value, of the curve with the abscissa, or horizontal axis.

a = the slope of the line. This depends on susceptibility.

The product of $C \times E \times \frac{1}{B}$ is given in Column VIII. If we plot the data (Column VIII) against temperature rise (Column IX) for subject A, our most experienced subject and the one least liable to variations in manner of breathing (see Column V), it will be seen (Fig. 3) that the points fall along a fairly straight line or zone which crosses the horizontal axis at a finite point. In his case, the value of the constant K is 170 and that of the constant a is 0.006. The data from all the other subjects are grouped, with three notable exceptions, fairly well about the line determined for subject A. Points above the line indicate hypersusceptibility and those below, hyposusceptibility. That is, points above show that the febrile reaction was severer than that predicted and those below indicate that the subject was more resistant than expected. Obviously, it is better to err in the direction of assuming hypersusceptibility rather than hyposusceptibility. The experimental points marked 18, 25, and 17 are important, therefore, since they result from errors in assuming that these subjects would have less severe reactions than actually occurred. If errors in this direction are prone to occur, this method of predicting or estimating the probable severity of the reaction is seriously misleading. We believe, however, that all three discrepancies are explainable.

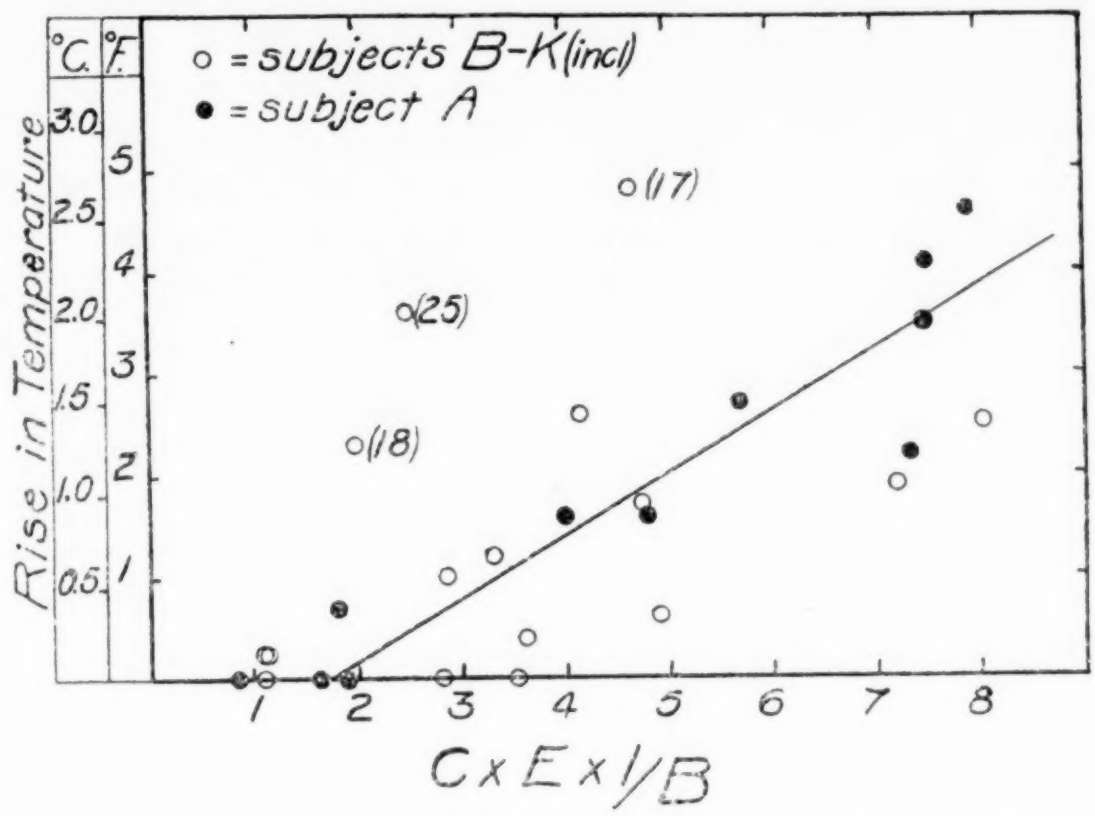

FIG. 3.—Data from Table 1, Columns VIII and IX, showing threshold dosage of zinc oxide fume. Abscissas are the product of three variables: fume concentration, C, and length of exposure, E, and the reciprocal of breaths per minute, $\frac{1}{B}$.

Experiments 18 and 25 were performed on subjects D and H, whose vital capacities are 4.5 and 5.1 liters, respectively (Table 1). Their expected normal minute-volumes were about 7 or 8 liters a minute. Breathing at a rate of 6 respirations a minute, as they did in these two experiments, their minute-volumes should have

been considerably less than 8 liters on account of the more effective lung ventilation consequent on slow deep breathing. Because this was their first exposure to zinc oxide fume, they breathed too deeply and during the experiments they attained minute-volumes of 10.5 and 11.7 liters, respectively, or almost double their normal expected physiologic requirement. This overventilation is unnatural, but it can be maintained very easily by the average subject for periods of fifteen minutes, as was done in these two cases. The effect of overventilation is always to make exposures to metal fumes more severe than they otherwise would be, since more fume particles penetrate to the depths of the lungs. We see the same sort of overventilation in subject A's experiment 2, in which his minute-volume was 10 liters. In his other experiments with slow breathing (experiments 4, 6, 7, 8, 9, and 11), he reduced his minute-volume to an average of about 7.5 liters.

The other point, experiment 17, applies to subject C, an experienced subject who breathed at his normal rate of 15 respirations a minute. The explanation in his case lies, we believe, in the fact that he is unusually susceptible and has had several febrile reactions from exposures which, in others, have produced no rise in temperature. In the experiments upon subjects C and A which we have previously reported (1), it was noticed that the vital capacities of both decreased steadily with the onset of an attack of the fume fever. Of the two, C's decrease was the more striking—53 per cent. as compared with 18 per cent. in the case of subject A, who is less susceptible. The unusual susceptibility of subject C may, perhaps, be explained by the fact that "Examination of the chest of C showed a fairly large number of persistent fine, moist râles at the left base which were present one-half hour after the inhalation and remained unchanged for a period of three days. Eight days later a few transient râles of the same character remained in this same location. Examination of the chest of A showed no variation from normal" (1, p. 90).

We use a concentration of 15 mg. per cubic meter as the threshold limit, because we have found that men exposed for eight hours (8) to concentrations of that order do not ordinarily acquire fever.

We found (4) that metal fumes other than zinc oxide will also produce fume fever and that there is a decided difference between the reactions produced by the various fumes. The suggested limit of 15 mg. of zinc applies to zinc oxide and presupposes that impurities like lead, cadmium, and copper do not occur in physiologically significant amounts. Further studies, made under actual plant conditions, will be necessary in order to determine whether or not this limit for zinc can be widely applied in industry.

Preventive Measures

Fume Concentration and Length of Exposure

The most practical means of preventing fume fever are (*a*) to reduce the fume concentration to the threshold level and (*b*) to make exposures as brief as possible.

In most instances, the fume concen-

tration can be reduced to the threshold level by applying suitable methods of ventilation. Especial attention should be paid to operations like skimming and pouring, which produce concentrations of 300 mg. and more per cubic meter—a condition which will induce attacks of fever after exposures of from five to twenty minutes and will generally pollute the foundry air."

In foundries where the fume has no economic value, the ventilating fan often discharges out of doors. This practice not only creates a local annoyance, but, in winter, it causes the loss of appreciable amounts of heat. Waste can often be avoided by passing the fume laden air through bag filters similar to those used in collecting zinc oxide in the metallurgic industry. In the modern foundry, this air, filtered free of fume, can then be recirculated, either in part or in whole. During the hot summer months when the foundries require disposal and not conservation of heat, the filtered air can be passed out of doors. In both summer and winter, atmospheric conditions in many foundries and their environs can thus be improved.

Where concentrations cannot be maintained at the threshold level, the second precaution—reducing the time of exposure—should be applied. When exposures are reduced to twenty minutes or less, we find that concentrations as high as 45 mg. per cubic meter can be tolerated.

Acquired Resistance

"It is probable that workmen have recognized acquired resistance to metal fume fever ever since the brass "shakes," "chills," or "ague" have been known." In the case of two of our own subjects, A and C, previous attacks of fever rendered them resistant (2) to heavy doses of fume which were administered within about twenty-four hours of their first exposure. A's first inhalation, experiment 11, caused a rise in temperature of 2.7°F. About twenty-four hours later he inhaled a dose some 50 per cent. severer than the first. His predicted rise in temperature[4] was 4.2°F., but his actual increase was only 0.8° to 1°F.

"Complete reliance on acquired resistance as a preventive measure is not justified, however." Turner and Thompson (22, p. 24) report that some men have attacks of fever two or even three times in a week." Our data, on only two cases, is insufficient to warrant generalizations on the extent of acquired resistance in industrial practice.

Respirators

"In plants where men are subjected to brief or intermittent exposures, there is no reason why respirators cannot be worn. In long exposures they are impractical, because, when efficient, they are apt to be hot and uncomfortable, especially if the subject exercises vigorously and perspires."

We have no difficulty in making suitable filters for respirators (23) at a cost of a few cents each. These filters are made of the fabric used by the New Jersey Zinc Company for collecting zinc oxide in its metallurgic plant at Palmerton, Pa. (24). After the surface areas are plugged by drawing through for a few minutes air

[4] Not shown on the curve of Figure 3 or in Table 1.

containing freshly prepared zinc oxide, the efficiency of the filter against fume particles like those of the zinc oxide we generated for our experiments (of the order of 0.4 micron (21)) is nearly 100 per cent.

Our experience with regard to the efficacy of respirators is similar to that of Burstein (11) who found that, when four subjects were exposed to zinc oxide in a brass foundry, the one who wore a respirator was not affected, whereas the other three had typical attacks of fever.

Effect of Sweating

"The employers and workmen at the brass foundry from which Thomson obtained his air samples were of the opinion that metal fume fever occurred much more commonly in winter than in summer, and they believed that this seasonal variation was not entirely due to differences in ventilation and hence in the concentration of zinc inhaled."

We were told that protracted sweating, if it took place within about four hours of the time of exposure, would reduce the severity of the febrile reaction or even prevent it completely. Walking home in the cold air after working in an atmosphere containing brass fumes, on the other hand, was said to hasten attacks of the fever. These statements have received some support in the literature (5) (7, p. 285) (25, p. 332), but apparently no attempt has been made to verify them experimentally.

In order to determine whether enforced sweating had any demonstrable prophylactic effect, subject D and subject A entered our psychrometric room (12) after inhaling zinc oxide (experiments 19 and 9, Table 1). Subject D entered the room two and one-half hours after his inhalation and subject A, four hours after his. The room in both cases was maintained at a temperature of 100°F., with a relative humidity of 95 per cent. Both subjects remained in the room for about fifty-five minutes, sweating copiously, and lost about 3 pounds in weight as a result.

"The data of the experiments show that neither subject obtained any measurable benefit from the sweating treatment. The anticipated febrile reaction occurred in the usual way and differed in no significant manner from the reactions previously described (1)."

These results should not be interpreted to mean that a hot bath, hot drinks, and the like are not pleasant at the actual onset of the chill and fever and may not reduce the duration of the reaction. The fever begins, in our experiments, six hours after the inhalation of zinc oxide and our sweating experiments were carried on purposely well before its onset.

Effect of Repeated Inhalations of Zinc Oxide

During the last two years, subject A has experienced thirty experimental zinc oxide inhalations for periods varying from five to forty minutes. He has inhaled a total of about 510 mg. of zinc of which we can assume that he retained about one-half, or 255 mg. At three different times in the course of these two years, he was examined clinically and by X-ray at the Peter Bent Brigham Hospital, Boston. The first of these examinations was made in July, 1926, another on Oct. 27, 1926, during an attack of the fever, and

the third eight days later (1). The first and last examinations were negative; the second showed transient effects which had disappeared by the time of the third examination.

In the zinc plant where Thomson took his samples and from which Batchelor and his associates (8) drew their twenty-four subjects, the most representative zinc oxide concentration was about 14 mg. of zinc per cubic meter. During an eight-hour working day, a man breathing at an average rate of 9 liters a minute in this atmosphere would inspire a total of about 62 mg., retaining approximately 31 mg. Detailed studies on the men exposed to these conditions showed "no acute nor chronic illnesses ascribable to zinc" (8, p. 361).

In a typical brass foundry, Thomson estimated that 13 mg. per cubic meter was a representative concentration, although the concentration varied considerably from day to day. (Indeed, men working in brass foundries are occasionally required to breathe concentrations of 370 mg. per cubic meter, or even higher.) In this particular foundry, the men worked on continuous eight-hour shifts. At periods of one and one-half hours, each furnace man skimmed four times, a skimming requiring about two minutes. In an eight-hour shift a man would thus be exposed to a zinc concentration of about 370 mg. per cubic meter for a total of about forty minutes. Assuming that he breathes eight times (6 liters) a minute, he would inhale at least 89 mg. of zinc. During the remainder of the working day, he breathes, presumably at a normal rate (9 liters a minute), a concentration of approximately 13 mg. of zinc per cubic meter. He would thus inhale about 50 mg. of zinc, giving a total for the day of 139 mg. inhaled, or about 69 retained. If workmen do not acquire the fume fever as the result of their exposure, there is no reliable evidence that daily inhalations of about this order produce chronic illness or permanent systemic damage.

In order to produce permanent damage in animals, Turner and Thompson used zinc oxide concentrations of about 1,900 to 2,500 mg. per cubic meter (22). In man, these concentrations would produce violent coughing after a few breaths. Moreover, since such high concentrations are very unstable, they clear up rapidly and will be found only in pipe lines, collecting bags, etc., in the metallurgic industries. A man would be incapable of working more than momentarily in such an atmosphere and could see but a few feet on account of the density of the fume.

The evidence of these various studies indicates that the effects of inhaled zinc, as encountered industrially, are noncumulative and that inhaled zinc does not, *per se*, produce chronic damage of any demonstrable sort. Nevertheless we are not satisfied to leave our conclusions at this point, for there is indirect evidence that frequent attacks of the fume fever may, in the long run, leave their mark.

Turner and Thompson (22) found that 102 of the 212 American brass-founders to whom they gave physical examinations had experienced attacks of the fume fever. They reported (p. 20) that "The workers who gave histories of zinc oxide poisoning were apparently in somewhat poorer phys-

ical condition than those who were exposed to the fumes, but not affected by them." The results of Guelmann's survey of Russian brassfounders (26) are similar in their implications. Both surveys fail to substantiate the theory (25, p. 351) that brassfounders as a class are unusually susceptible to pulmonary tuberculosis and other respiratory diseases.[5] Nevertheless, repeated inhalation of zinc oxide fumes in sufficient quantity to produce the fever are considered inadvisable and it is believed that such exposures should be avoided.

Summary

From the results of twenty-seven experimental inhalations of freshly generated zinc oxide participated in by ten subjects, men and women, under laboratory conditions, a formula is derived for expressing threshold doses of zinc oxide in terms of fume concentration, length of exposure, and rate of breathing. As a measure of the severity of the reaction, the maximum increase in oral temperature above the normal is used.

It was found in a metallurgic plant that concentrations of 14 mg. of zinc oxide per cubic meter (measured as zinc) produce no reaction in the average subject after an exposure of eight hours and that, in laboratory experiments, 45 mg. can be tolerated for twenty minutes. In both instances, the zinc oxide was exceptionally pure.

As preventive measures, it is suggested that high concentrations of zinc oxide fumes be avoided, that local exhausts with air filters and partial or total recirculation be applied, and that respirators be used for brief, intermittent exposures when ventilation is not applicable.

Physical examination of 212 brassfounders by the United States Public Health Service showed that those who experienced attacks of metal fume fever were "apparently in somewhat poorer physical condition than those who were exposed to the fumes, but not affected by them." If the dosage of zinc oxide inhaled is insufficient to cause the fever, there is no evidence that daily inhalation of the fume does chronic damage."

[5] In the published statistics (25, pp. 351 and 353) no distinction is made between brassfounders and brass workers in general. This fact may account for these discrepancies.

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THE STORAGE BATTERY INDUSTRY*

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INTRODUCTION

THE making of storage batteries, or electric accumulators as they are called in England and in European countries, is one of the most important of the lead using industries and one that is attended with a risk of plumbism far above the average lead industry. This manufacture has of course increased enormously of late years, owing to the increase of automotive vehicles and to the introduction of the radio. In 1914 the five largest factories in the United States employed a little more than 900 men in lead work; in 1926 the nine largest were employing about 7,500 in such work.

There are two forms of lead storage batteries—those destined for stationary engines and those for automotive vehicles. The former, relatively unimportant in the United States compared with the latter, are for use in country houses and for the lighting of trains. These should be durable and in them weight is no objection; therefore such batteries are made with so-called Planté positive plates and pasted negative plates. The Planté plate is solid lead, corrugated or ridged in order to increase the surface. For vehicles and for radio use, the batteries should be light and as cheap as possible; they are therefore made with pasted plates for both positive and negative. The pasted plate is a molded leaden grid, the interstices of which are filled with a paste of lead oxides. Both Planté and pasted plates are "formed" or charged by the passage of an electric current, the effect of which is to change the metallic lead of the Planté positive plate and the litharge-red lead of the pasted positive plate to a higher oxide, the brown peroxide, while at the same time the litharge of the negative plate is changed to spongy metallic lead. During the discharge the sulphuric acid combines with the lead peroxide in the positive plate and the spongy lead of the negative plate to form lead sulphate in each.

Formerly the positive pasted plate was made with red lead and the negative with litharge paste, but the tendency now is to use litharge as much as possible for both plates because it is cheaper than red lead. Negatives are always made with litharge paste, but a little red lead is often added, because litharge paste is sticky and the addition of red lead makes it easier to handle. The paste for positives has more red lead, but the proportion of litharge in it is continually increasing. A larger number of positive plates are always made because negative plates are longer lived; service stations therefore require more positives for repair work.

The features in a storage battery works which are interesting to the

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industrial hygienist are: first, the dry lead oxides; second, the oxide paste; third, the dry pasted plates, which must be transported and handled; fourth, the lead burning of pasted plates; and fifth, the molding or casting of the grids. The early processes, which have to do with metallic lead only, give relatively little trouble; in fact, months may pass without the appearance of a case of lead poisoning in the molding room. But with the entrance of the oxides into the process, the situation has changed, and from that time on oxide dust becomes a danger, and only the strictest cleanliness, only eternal vigilance, will prevent lead poisoning in the mixing, pasting, finishing, and assembling departments. Lead fumes also are produced in lead burning, but the risk to the lead burner comes much more from the oxide dust, which he detaches as he handles the dry pasted plate, than from the fumes caused by the flame.

Description of Processes in Storage Battery Industry

The following is a brief description of the different processes in making storage batteries.

Molding or Casting Grids and Planté Plates.—This work differs in no way from that in any department that is making molded lead goods. The risks are slight and the prevention of lead poisoning is relatively simple. All that is needed is a properly constructed hood, with an exhaust over the kettle, and cleanliness of operation so that lead dross and scrap are not allowed to accumulate on the floor. Wooden floors should never be allowed, for it is impossible to keep them clean from particles of lead, nor should any of the later processes go on in the same room with molding.

Making Paste.—This involves opening kegs and dumping dry red lead and litharge, blending them in the right proportions unless this has already been done in the oxide plant, and mixing the powder with acid and other constituents which are kept secret.

Pasting Plates.—The paste is smeared over and pressed into the leaden grids; pasting may be done by hand or by machine. The danger here is from dry paste, which collects on the benches, drops on the floor, and is spread over the men's clothes. The finished plates are stacked up on benches, on shelves, or in receptacles, and as they dry the dust is blown off the surface or falls and accumulates. In order to prevent danger, dampness and wet cleaning are necessary. The floors and benches should be of impervious material, kept damp throughout the working day, and thoroughly washed at the end of the day. The plates should be wet when they are handled, and no dry plates should be allowed to accumulate in the pasting room. Traveling belts or receptacles for plates should be washed often enough to keep them clean.

Drying or Pickling Plates.—The wet pasted plate may be dried in a warm chamber or it may be pickled, that is, dipped into an acid bath which forms a coating of sulphate on the surface. When this is done, a solid smooth surface results which is productive of very little dust. These pickled plates may be made up at once into batteries without drying, but if they are to be shipped as such

they must be dried. It is of course far safer not to dry them. Drying is accomplished in ovens or in heated rooms, and the plates may be sent directly through the heat without being handled or they may be handled several times, each time increasing the dust hazard.

Formation.—This process is of relatively little importance. The dried or pickled plates, loosely connected by twisted metal bands or by soldering—"tacking"—are placed in weak sulphuric acid and left while an electric current passes through them. Unless there is great carelessness in handling the dry plates, there is little hazard in this department. The fumes from the acid are disagreeable to a novice but the men easily become accustomed to them and apparently no harm results from this slight exposure.

Finishing.—A finished plate is ready for assembling or shipping. This process may follow pickling or may not come till after formation. Usually finishing includes cutting or sawing apart plates which have been cast and pasted in pairs, which is the customary procedure. The edges may also be trimmed and the projecting end which serves for linking up the plates into groups, and which is known as a "lug," must be freed from oxides either by brushing with a wire brush or by scraping with an instrument or simply shearing with a knife or a punch press. The more the lug has to be cleaned, the greater is the hazard in this department, because of the greater amount of oxide dust produced. Pickled plates are less dusty than those which have not been treated with acid. In some factories there is more lead poisoning among finishers than even among pasters, but fortunately mechanical lug cleaning is largely displacing handwork and it is perfectly possible to make the machines dust proof. It is, however, necessary to provide slotted or perforated benches with a down draft exhaust and a closed receptacle below to catch the dust which falls from the plates.

Assembling.—The finished plates are set in an iron holder known as a "jig;" then a leaden plate strap or pillar is burned on, making groups of positives and of negatives. These are then fitted together so that a negative plate comes opposite a positive plate, and separators, thin slips of wood or of rubber, are slipped between. Leaden connecters and also terminals are then burned on. This work is called lead burning, although it differs from the so-called "chemical" lead burning.

Charging.—If negative plates are dried after formation they lose the charge and a second, so-called "booster" charge is necessary. Conditions here are the same as those described under *Formation.*

Burning Containers.—Some of the batteries are placed in lead lined containers which are made by lead burning. The risk of fumes is greater here than in assembling, if the containers are so large that the operator must work with his head inside.

Working up Scrap and Dross.—All the large plants melt down lead scrap and a few smelt dross and oxides. This last is a separate trade and the precautions to be used are those which have been worked out for the smelting trade, involving the prevention of dust by sprinkling all charges and the prevention of fumes from feed door

and from tapping door. This is rightly recognized as one of the most dangerous departments, if not the most dangerous.

Salvaging Old and Defective Plates.—Old storage battery plates and defective plates are often shipped to a refinery, but sometimes the grids are freed from the oxides and melted down with other lead scraps, while the oxides are sold to the refinery. This work is always productive of dangerous dust.

Sealing Containers.—The compound or composition used for sealing the finished battery is a hot mixture which contains asphalt or tar as its chief constituent. The fumes are not injurious to health but are disagreeable enough to require their removal, and in all well-managed plants they are not allowed to escape into the air.

Storage Battery Industry in the United States in 1914 and in 1918

The first investigation I made of this industry was in 1914, for the United States Bureau of Labor Statistics. At that time there were only five large storage battery factories and the men employed in work exposing them to lead numbered less than 1,000. In connection with this investigation I tried to discover how much lead poisoning had occurred during the preceding year among the force employed, and, as records were available from only three of the five factories, I was obliged to supplement these records with examination of hospital records and interviews with physicians. In this way 164 cases of lead poisoning came to light, which would make a rate of 17.9 per hundred employed. This figure could not be regarded as accurate, however, because there was very meager information with regard to three of the five plants. The employees were of the shifting, migratory class, and not only was there much more poisoning than could be traced, but the force employed certainly very much exceeded the figure 915 which represented the payroll at any given moment.

It was evident from the study of these cases that work with the oxides was much more dangerous than work with metallic lead. Thus, in two plants employing 619 men the rate of lead poisoning per hundred employees was 1.7 for molding and 59.4 for mixing and pasting. Mixing, alone, including the filling of ironclads, was responsible for a rate of 40 per hundred. The form of lead poisoning was acute and developed rapidly. In 41 out of 70 cases the period of exposure was less than six months; in only 17 was it more than a year.

At that time the hygienic conditions were never more than fair and in some instances they were very bad. The impression still seemed to prevail that lead fumes are the chief danger, and therefore much more money was spent in exhaust apparatus to carry off fumes from the melting pots than in the prevention of the far more dangerous oxide dust. The opening and dumping of the oxide kegs, the blending of oxides, and the making of paste were carried on with a good deal of recklessness in some plants, although in others there was an evident effort at supervision and care. Hand mixing of paste on the pasting benches was still to be found

at that time. It has fortunately disappeared now from all but the smallest plants. The pasting rooms were none of them above criticism, either in construction or in upkeep, and the subsequent handling of the pasted plates was always productive of dust. Only one plant had mechanical cleaning of lugs.

In 1918 I was one of the members of a joint federal committee from the Ordnance Department, the Public Health Service, the Bureau of Labor Statistics, and the Women's Bureau of the Department of Labor to make an investigation of the industry in order to determine whether it would be safe to substitute women for men in any process in any factory. Because of the well-known danger to women of employment in lead work, this meant that a factory that wished to employ women must not only use proper precautions but separate relatively safe from dangerous processes, so that a woman employed in the former would not be endangered by working in close proximity to the latter. The number of large plants had by that time been increased to six and the five original factories were all enlarged to meet the war time demand. This investigation disclosed a decided improvement in two of the large plants, two others were in a fairly good condition, and only two called for really severe criticism from the committee.

English Accumulator Factories

In the fall of 1925 it was my good fortune to be able to visit the four principal accumulator factories in England and the famous German works in Hagen. The British have recently made a study of the electric accumulator industry in that country, and a report of the official investigation was published in the issue of This Journal for October, 1925.[1] The Regulations recommended as a result of the investigation were being put in force when I was in England and I was therefore able to see something of what conditions had been like before and what were the dangers which the Regulations were designed to control. This is not the first time that rules have been formulated for the industry; indeed it has been controlled for twenty years by a Sanitary Code to which the present Regulations are only supplementary.

The difference between accumulator works in England and those in the United States is the same as the difference found in any of the dangerous trades as I have seen them in these two countries. The English factories are at once less excellent than our best and less bad than our worst. This follows from the fact that in England industrial hygiene is under efficient governmental control by trained inspectors who carry out rules formulated by experts. The employer knows that if he follows instructions his workers will be safe, and he is thus satisfied. The employer in the United States, who experiences little if any outside control over his plant, either neglects the whole situation with results that are sometimes shocking or takes it as his personal responsibility, and in coping with it often becomes so keenly interested that he goes beyond the necessary precautions

[1] Price, C. W., and Bridge, J. C.: The Manufacture and Repair of Electric Accumulators. This Jour., 1925, 7, 451.

and produces the really admirable conditions which are to be found in our best plants. Fortunately, the better plants predominate, and that fact gives us a high average, but unfortunately does not help the hundreds of workmen employed under less favorable conditions.

The new British Regulations were made in a way which struck me as being interestingly democratic but which would be quite impossible in the United States. They were formulated at a joint conference between the experts of the Factory Inspection Department of the Home Office, representatives of the employers, and representatives of the trades-union. In the United States, of course, we lack two of these bodies, for we have no government experts and no trades-union in the industry. The nearest approach to the British system that I have found in a dangerous trade in the United States was devised by Col. Lewis T. Bryant, late Commissioner of Labor of New Jersey, and Dr. Francis D. Patterson, formerly Medical Director of the Department of Labor and Industry of Pennsylvania, who just before and during the war joined in the formulation of several sanitary codes for poisonous trades, in conference with the employers. However, since these industries were also quite unorganized, the workmen had no voice in the deliberations.

Molding.—The English accumulator factories[2] have on the whole more handwork than is found in large factories in the United States. Their molding rooms are very good and are usually freer from soapstone powder than most of ours. The Chloride Electrical Storage Company, Limited, has over each melting pot a wide hood with an exhaust extending over the receptacle for dross which is covered when it is carried away. This is a very good feature which might be copied in some of our works. The scattering of scrap is prevented in this plant by placing a big removable pan under the punching machine. In another molding room in this factory a battery of eight kettles, four on each side, is covered by a long exhaust pipe with a lid over each which the man lifts when he is at work. The kettles are so placed that no two are directly opposite, but each man as he lifts his lid faces a closed space. The Tudor Works uses soapstone powder for Planté positives only. Other molds are prepared with soap and water instead of soapstone. Here the dross is skimmed into a covered skip car.

Making Paste.—Dumping the oxides and blending and mixing present difficulties in every plant. In the United States there seems to be an impression that a very elaborate and expensive apparatus is essential if excessive dust is to be avoided; in the absence of such apparatus practically nothing may be done, and the mixing department may be regarded as an inevitably dusty and dangerous spot. I should like, therefore, to describe the simple method used in the Tudor Works, one which could easily be copied with very little

[2] The four factories visited were the Chloride Electrical Storage Company, Limited (a branch of the Exide Company, Philadelphia), and the Tudor Works, both near Manchester, and the Hart and the C. A. Vandervell companies in London.

expense.[3] The dump is on the floor above the mixing machine. Beside it stands a barrel into which the paper which lined the oxide keg is dropped. On the other side stand the scales. Three exhausts are placed here; one, which is fixed, is over the barrel for papers, and the latter must stand exactly in the right place. A second fixed exhaust is over the dump; a third, adjustable, is over the scales. These are all in a corner of the room beside open windows. The man wears a respirator while dumping and works with care, so that there is almost no trace of escaping powder. The device used by the Chloride Electrical Storage Company is the same as the very excellent one developed by the Exide Company in Philadelphia.[4]

Pasting Plates.—The most conspicuous feature of the pasting rooms in English factories is the floor, which is always awash with water. The men stand on wooden platforms and wear wooden shoes (clogs) which are provided by the employer, as are also washable suits and caps. In the Hart Works there is a pasting room with white walls which had been painted six months before my visit and which showed scarcely a trace of red on the surface. In all the English pasting rooms the emphasis is laid on dampness for the prevention of dust, although the new Regulations do insist on the installation of an exhaust, probably along the far side of the bench, to draw the air away from the paster. The oxides which are carried away by the water flowing over the floor go to a sump where they settle out and are recovered. In the Tudor Works I noticed that the sheet lead covering of the red lead pasting benches slopes slightly to a drain in the center, and the raised edge of the bench has been fitted with a wooden cover which lifts off and is washed at the end of the day. All surfaces in the pasting room must be wet cleaned. In the Vandervell plant the edge of the pasting bench is not raised, but is fitted with a trough 3 inches wide which is to catch the paste that falls, and which can be washed out.

It is customary in three of the English plants to get rid of the excessive moisture in the pasted plates by pressing them between thick cloths or felt pads instead of using paper as we do. These cloths or pads, which of course become impregnated with oxides, must be dried somewhere and used again. It is a troublesome feature and so far is not satisfactorily dealt with, for it is hard to find a good place to dry the cloths and to store the dusty things while they are waiting to be washed.

Drying and Storing Plates.—On the whole the arrangements for drying plates and for transporting and storing dried plates are not so good in English factories as they are in the best factories in the United States, with the exception of those of the Chloride Electrical Storage Company, because in the English method there is more handling and that means more dust. Pasted plates must be lifted and placed on trucks, then lifted off and put on shelves or hung on racks in the drying room, and then go back again to trucks and to the storage rooms and finally on trucks

[3] See description of method used by the Philadelphia Storage Battery Company and by the Westinghouse Union Battery Company, page 359.

[4] In their new works in Crescentville.

again and to the forming room. It is, of course, very difficult to keep drying and storing rooms free from dust under such conditions, and to protect the men engaged in transporting.

Finishing.—Finishing has been carefully planned out and the benches are slotted or provided with a perforated plate with a down draft. A down draft carries off the dust from the brushes used for lug cleaning and from the machines used for stamping. There is little handwork done on lugs; almost all the work is mechanical.

Lead Burning.—Lead burning in plants in the United States is regarded as one of the least dangerous processes, especially now that it is carried on very largely by machine. The English take it more seriously, and the new Regulations require a hood with exhaust to carry off the fumes; when the burner must move from place to place the matter of ventilation thus presents difficulties. The Tudor Works has solved the problem by swinging the hood on two metal rods and providing it with a flexible metal ring exhaust pipe so that it can be moved from place to place on the bench. Actual lead burning of the linings of containers cannot, of course, be handled in this way. That is still a problem in England as it is in the United States. The only solution I have ever seen was in the German works in Hagen where a method is used that will be described later.[5]

Working Up Scrap and Dross.—Three of the four English plants melt their own scrap, and two smelt dross and oxides. Since these processes come under the head of smelting, these departments have rightly been placed under the special rules governing the smelting trade, which are very strict with regard to dust and fumes. All the scrap, dross, and old plates must be dampened to keep down dust, and the furnaces must be provided with devices for the prevention of fumes.

Physical Care.—The physical care of the workmen in the English plants is also under strict regulation, which means that no plant is allowed to fall below a minimum standard. Usually one does not find so lavish an expenditure as in the best plants in the United States, but, on the other hand, one always finds the essential needs provided for. It is impossible for such conditions to exist in England as still obtain in the United States under negligent employers. Washrooms are always provided with warm water, nail brushes, soap, and towels, which, however, may be roller towels. Baths must be provided, and the tub bath is still much in evidence. Thus in the Tudor Works, the bathhouse contains six tub baths. Each lead worker must take a weekly bath, the record being kept by the man in charge. The washroom in this plant is divided into two parts; the man enters at one end, takes off his overalls and hangs them on a numbered hook, and goes to the wash basin which has hot water, soap, brushes, and towels. A wooden platform is placed here on the cement floor. Then he goes on to the other side, where his street clothes hang on a numbered hook, and where there are wooden benches. This side

[5] See page 357.

of the room is heated, in order to dry his street clothes in wet weather. All these details are covered by the Regulations and the provision is entirely adequate without one touch of needless expense.

In general, factories in England have better provision for feeding their employees than have factories in the United States, although when the latter do undertake to provide lunches they usually go further than the former. Apparently the English workman is not content with a cold dinner pail lunch; he wants not only hot tea, but a hot dish, and even in those works where there is no restaurant there is a kitchen with ovens for heating food and hot water is provided for tea. The Chloride Electrical Storage Company has a big lunch room where the men can eat their own food, which is heated for them, and get boiling water for tea, or where they can buy a meal for eightpence consisting of meat, bread, potato, vegetable, and pudding. The Vandervell Company provides at 10 in the morning a pint of milk and two cakes, the men having twelve minutes off to go to the canteen for it. The Tudor Works also gives the lead men a pint of milk a day, and in summer they give coffee to the men in the casting room so that they will not have to drink so much water, a curious idea to us water drinking Americans.

Medical Department.—The British Regulations prescribe monthly inspection of the lead men, of all boys under 16 who apply for work, and of all women employed in the assembly room whether they are handling lead or not. The newer Regulations have been modified to insure a medical examination within the seven days immediately preceding or succeeding the day of first employment. The rooms and the equipment provided for the physician are usually far below the standard in the United States, although again, hardly so bad as our worst. The Chloride Electrical Storage Company has gone beyond the Regulations and has a weekly examination for all who are in especially dangerous work, a fortnightly examination for women and for men in the next class of dangerous work, and a monthly examination for others. Employees suffering from lead poisoning never go back to lead work. This Company also has installed a dental dispensary complete for all sorts of work at very low rates. All new employees are examined and about 130 are treated each month. This is, of course, much more necessary in England than in the United States, for apparently dentistry is regarded by the British working classes as a luxury reserved for the rich. Nowhere, not even in the mercury using industries in the United States, have I seen such an appalling condition of the teeth as one sees quite commonly in England among the wage earners.

A German Factory

The factory of the Akkumulatoren Gesellschaft, in Hagen, is probably the most famous in the world, and for many years it stood at the head so far as hygienic regulations were concerned. This factory was the first to undertake a systematic campaign against lead poisoning which was based upon its early detection through

regular blood examinations. In 1902 Wagener[6] published a study of the storage battery industry (*Accumulatorenfabriken*) in which he reported that in 1894 the number of cases of lead sickness was found to be "frightfully high" (*erschreckend hoch*). In five small factories having eighty-five workers in all, twelve workers during one year became sick with lead colic (making a rate of 14 per hundred). The application of strict Regulations, however, brought about a marked change. Thus in 1897 the number employed in lead work in the Hagen factory was only 189, but there were forty cases of lead poisoning, making a rate of 21.16. The following year the number fell to 7.55 per hundred and by 1901 it was only 0.97.

These Regulations require adequate ventilation, and floors impervious to water, not made of wood or of soft cement or covered with linoleum in any room in which lead is handled. The walls must be smooth, covered with washable paint or whitewashed once a year. Casting, finishing, and pasting must each be in a separate room. Hoods must be placed over melting pots, over lead burning, and over paste mixing and pasting, and dust must not be allowed to escape in the course of cutting and finishing. Floors must be cleaned with water twice a day. There must be separate lunch rooms, separate dressing and wash rooms, washing to be compulsory, with one bath a week. The employer must provide soap, towels, and brushes, and a full suit of working clothes with a cap. No women or minors may be employed.

The Hagen plant goes beyond the Regulations, for though the law requires only monthly medical inspection they have it weekly. If there is any suspicion of plumbism, a blood examination is made; and if stippled cells are found, the man is kept on lead free work until the stippling disappears. Dr. Böttrich has been in charge of this work since 1890, and he holds that all stippling shows an abnormal condition which disqualifies a man for lead work whether or not it is caused by lead poisoning. I saw him examine 150 men, mostly lead burners and laboratory men. It was a brief and superficial examination, but probably quite adequate for a physician who was seeing these same individuals every week. It was largely an examination of personal habits. Böttrich went carefully into the condition of the teeth and of the hands, and occasionally he would smear a 5 per cent. solution of sodium sulphide over the man's hands to show him that he had not washed enough to get rid of the lead. This is really a very good piece of educational demonstration, for the black color that comes out on the man's hands startles him and attracts the attention of all the other men in the room.

The washroom in this plant is the largest I have ever seen, actually one basin for each man, rubber workers as well as lead men. These are good, white enameled tip-over basins. The floor is tiled and the walls are of white tiles. The men are instructed to wash first without soap, then with soap and

[6] Wagener, O.: Ueber Gesundheitsschädigungen in Accumulatorenfabriken und gesundheitspolizeiliche Maassregeln dagegen. Deutsch. Vrtljschr. f. öffentl. Gsndhtspflg., 1902, *34*, 529.

brushes, and then to use glycerin. There is also an excellent building for baths with tiled floors and very pretty blue, black, and white tiles covering the walls. The men must bathe once a week either in one of the twelve tubs or under one of the many showers; the majority prefer the latter. There are double lockers, for street clothes and work clothes. The lunch room is big and plain, but pleasant, and there is an hour at noon. Most of the employees go home for dinner. I was struck by the large number of old and middle-aged men employed here—a decided contrast to an American factory. In the middle of the morning, milk is furnished to the lead men, and in order not to interrupt the work and at the same time not to risk getting lead into the men's mouths from the moustaches which most of them wear, Dr. Böttrich devised a cheap tin drinking cup with a spout, such as is used in hospitals. A car with these cups already filled with milk goes to each department, and the men can drink from the spout without risk of carrying lead dust into their mouths.

The problem of prevention of plumbism is simpler in this plant in Hagen than in a plant in the United States because the majority of batteries made in Germany are still for stationary use and therefore are made with Planté positive plates. This greatly diminishes the amount of pasting and also of dumping and mixing oxides, and the subsequent dusty drying and storing, cleaning and finishing. The casting room is excellent, very large, with a fan in the wall. All the kettles are closed, opened only for feeding, and all casting is mechanical, yet as an additional precaution hoods are placed over the kettles with, however, only a natural draft in the pipe. The floor is very clean and continually sprinkled. Under each cutting machine is a pan, and no scrap is scattered about. Ninety per cent. of all plates are Planté positive with pasted negative—the latter is a double plate of soft lead on hard. The molding of the pasted negatives is done in a separate department; here the kettles are open, but the lead is covered with a thick layer of charcoal, and there are hoods with natural draft. The room is large and very well ventilated. Soapstone is used ordinarily, but for small plates with fine grids they use lycopodium.

This was the first plant to have mechanical pasting installed. It is carried on in a large, airy room with a fan in the wall, but with no local exhausts, which are really not needed at all. The paste comes wet and steaming in a car and is shoveled into the supply for the machine which runs down the center of the room. The damp, pasted plates are taken off at once and sandwiched between two grids. No paste is allowed to fall to the floor, and the whole room is scrupulously clean and free from dust. Some hand pasting is still done; I saw nine men in one room, seven in another, and two in a third. The details here are not so well worked out as in England, and these little departments do not come up to the standard of the rest of the plant, nor is the assembly for auto batteries so good as in the plants in England or in the best plants in the United States. Probably the fact that hand pasting is a minor department employing relatively few men explains why less

attention has been paid to it. The handling of scrap and dross is careful and excellent. Scrap is heaped in the center of the floor over a trap door which is opened at night allowing the scrap to drop through to a melting pot below. A very clever device is seen in the lead burning of linings for receptacles. They make the lining by winding sheet lead around a form, and burning the edges; then they slip it off the form and drop it into the box, which brings the seam on the inside and a perfect joining on the exposed side. This means that the fumes formed by lead burning can easily be carried off, and the man never has to put his head inside a large receptacle, as he does in the factories in England and in the United States. In the Hagen plant they use a hydrogen-air flame, which is reducing, and thus they obviate the formation of lead oxide. There is an excellent installation for the refining of lead scrap, but they do not undertake any smelting process.

A very interesting department at Hagen is the so-called "psychotechnical laboratory" for testing and training new men. It is in charge of two young experts, and it seems to me of great practical value. They endeavor not only to select the men for the different jobs but to give them enough training before they are sent down to the shop to obviate the sense of failure which lies at the bottom of so much labor turnover. For instance, the pasting department needs a new man. The applicant is shown in the laboratory all sorts of pasted plates illustrating successes and blunders. Then he is put to work and instructed much more carefully than he could be by a fellow workman. The effort is made to teach him to work rhythmically, which means easily and efficiently. As we all know, pasting is easy for an adept but difficult for a beginner, and most pasting gangs consist of a few adepts, who work without fatigue and make high wages, and a large body of floaters, who work under an exhausting strain in their effort to keep up with the skilled men and make as good wages. The great majority fail and quit. This German experiment would seem to be worthy of a trial in plants in the United States.

Storage Battery Industry in the United States in 1926

During the past year, 1926, I have made a third survey in this country, covering nine plants. This investigation made a very gratifying impression, even with foreign standards in mind. Of the nine plants, four would certainly come in Class A and two in Class B, but plans were shown to me in one of these which, when carried out, will bring it also into Class A. The other three still have certain departments which would not pass the scrutiny of British or German inspectors.

Molding.—The essentials to be considered in the molding department are the prevention of the following: lead fumes, lead dust, the escape of coal gas, and excessive soapstone dust. In general, the molding rooms conform to requirements in this respect. They are usually high, roomy, and amply supplied with windows; the lead kettles are covered with hoods and the pipes of these hoods have good exhaust drafts. Only one plant uses

illuminating gas as heat for the kettles, in a poorly ventilated room. In the others, oil or electricity is used for heat. The Crescentville plant delivers the molten lead through pipes to the kettles from an electrically propelled truck. Dross is not always carefully handled, and the hoods over the kettles are sometimes too narrow to catch the fumes from the dross receptacle.

As for the soapstone dust which is excessive enough in some molding rooms to give a very untidy appearance, it is a question how serious a menace to health this may be. There is no evidence that a dust of this character produces any harmful effect on the lungs, if indeed it ever reaches the lungs. Certainly the greater part is mixed with the saliva and swallowed. But it would not be safe to assume that the swallowing day after day of large quantities of a dust even as inert as soapstone would be quite without effect on the human stomach. The only investigation of this question, so far as I know, is one which was carried on in the Institute of Occupational Diseases in Moscow in the fall of 1924, where rubber workers, who also are exposed to great quantities of soapstone dust, were undergoing a physical examination to determine the effects, if any, of their work. The one feature which seemed to be possibly connected with this exposure was a high degree of gastric achylia, pointing to an atrophy of the gastric mucosa.[7]

However this may be, it is certainly desirable to do away with excessive amounts of soapstone dust. The Prest-O-Lite Company discards soapstone altogether, and greases the molds with acetylene smoke, passing the flame lightly over the mold once in every hour or hour and a half. This is not enough to make the air smoky. The Westinghouse Union Battery Company uses this method for some molds; on others they use a small quantity of soapstone.

In the few plants in which Planté plates are still made, for railway lighting, the conditions in the molding rooms are like those in molding grids, and the risks are similar. There is nothing complicated in the precautions needed to prevent lead fumes from the kettles, and the rolling, cutting, trimming, and straightening of the solid plates are all attended with a minimum of risk.

Dumping Oxides.—The prevention of dust in removing red lead and litharge from wooden barrels or steel containers to the blending apparatus is a difficult task and one that is usually too difficult for the management. The dumping room is likely to be regarded as a hopeless problem and is given over to dust; the only method of protecting the men is to keep them out of the room as much as possible and to give them respirators when at work. The better plants also make a decided effort at personal medical supervision of the few individuals employed in this work. The impression seems to be general that only a very expensive and complicated apparatus can be depended on to prevent dust in dumping and blending. Such an apparatus is to be seen in the Crescentville plant, where conditions in both blending and mix-

[7] See Hamilton, A., and Hilles, R. E.: Industrial Hygiene in Moscow. THIS JOUR., 1925, 7, 47.

ing departments are admirable. Nevertheless a simpler form of apparatus may work very satisfactorily, as for instance the one already described in the Tudor Works, near Manchester, England, and the devices used in the plants of the Westinghouse Union Battery Company and of the Philadelphia Storage Battery Company.

In the latter plant, the drum containing litharge is conveyed on rollers to a big box having a door which covers the dump. The lid is taken off the drum and a holder inside the box is fitted closely around the neck of the drum. The door of the box is closed, and the drum is inverted by a lever which is operated from outside. An exhaust pipe connected with the box carries off the dust, and the blender into which the litharge falls is enclosed, and no dust escapes. The device in the Westinghouse Union Battery Company is also simple. Here a big, movable hood with a strong draft is adjusted over a conical metal receiver which stands on the scales. The oxides are scooped out and dropped carefully into this receiver, which is then caught by its two handles by a traveling crane and carried to the blending machine. The receiver is fitted over the opening of the blender, the valve closing the opening is drawn to one side, and the oxides fall into the blender. After blending, the oxides drop to the mixer on the story below.

Those plants which buy their oxides in steel containers have less of a dust problem than those which have to handle wooden barrels, for the latter are never dust proof and the powder leaks out and is scattered everywhere, from the landing stage to the blending room. Moreover, the steel containers go back to the oxide plant, while the dusty barrels have to be disposed of. Mr. R. J. Hoffman, of the Prest-O-Lite Company, told me that it is their practice to wash out empty oxide barrels which have large crevices between staves and that in one case about 2 pounds of oxide were recovered. Of course rolling these barrels and stacking them up and loading them to be taken away will produce much dangerous and quite unnecessary dust.

Mixing Paste.—Hand mixing is no longer done on a large scale, and never by the individual paster. The mixing department is not always separate from the dumping and blending departments, and when it is not there is usually a dangerous amount of oxide dust about. The best department I have seen is in the Crescentville plant, where five closed mixers operate, with no escape of dust, in a special room separate from the blending department. In the Philadelphia Storage Battery plant some handwork is still done in the mixing room. The mixer stands on a high platform, working at his steel covered bench under a hood the edge of which comes against the upper part of his chest. A pane of glass in the hood and a light underneath allow him to see his work, and an inward draft under the hood protects him from the escape of dust.

Pasting Plates.—When we first heard of the mechanical pasting of plates which was used in Germany we hailed it as a great improvement, one which would do away with most of the danger in this department. This has not proved to be true. Machine pasting as carried on in the United

States may be very dangerous because it is done in a filthy manner, while hand pasting may be rendered practically safe simply because it is done with care and scrupulous cleanliness. The whole thing is a question of intelligence and real solicitude. It is important to remember that the danger in the pasting room comes not from fumes but from dust, and it is a mistake to install an expensive exhaust system and neglect the surfaces of benches and the cleanliness of the floor. This is emphasized quite rightly in the British Regulations and has been acted upon in some plants in the United States. Thus, in the excellent pasting room of the Willard Storage Battery Company, everything is kept as wet as possible. The pasting machine is wet. The floor, which slopes to a drain, is washed every night and is sprinkled frequently with water containing magnesium sulphate. This salt has the property of collecting water from the air and as the water drains off there is left over the floor a light coating of the salt which, by virtue of its hygroscopic property, produces a slight dampness, especially where the men's feet crush it. The oxides which are washed down the drain are collected and recovered. What seems to me the best treatment for the pasting room floor is the one used by the Prest-O-Lite Company which has adopted the magnesium sulphate idea from the Willard Storage Battery Company but has used it even more efficiently. All floors here are covered with a thick layer of sawdust, wet with magnesium sulphate water, and frequently sprinkled. This sawdust can be gathered up without any risk of dust and sent to the furnace for recovery of the oxides.

The cleanliness of pasting benches is very important, and so is the consistency of the paste, for the moister the paste is the less risk there is of dust. Paste should never be allowed to fall on the floor, where it dries and forms dust. The Gould Storage Battery Company has placed a removable wooden trough along the front of the bench, with a raised edge to catch and hold falling bits of paste. This is taken off and washed clean. The Philadelphia Storage Battery Company has a hopper shaped pasting table, of galvanized iron, covered with a big iron pan which is so placed as to leave a 2-inch opening along the front edge to the hopper below, in order to catch the paste and keep it from falling on the floor. The wire net on which the pasted plates are laid also opens to the hopper below.

It is essential to keep all surfaces clean in the pasting room, not only the pasting bench but the benches or shelves where the finished plates are stacked up and the receptacles in which the plates are transported. There is hardly a pasting room which does not reveal dangerous accumulations of oxide dust on such surfaces. In this respect the Prest-O-Lite Company has perhaps the model department. The benches are washed at noon and at night. Along the edge of the pasting bench is a triangular trough, shallow and narrow, filled with water to catch and render harmless all falling bits of paste. The pasted plates are laid at once on a traveling belt which is constantly kept wet and clean. All temporarily unused benches

are kept perfectly clean and even the platforms on which the pasters stand are washed at noon and at night. In addition, there is a hood with a strong exhaust draft placed at the back of the pasting bench. The method of handling the papers used to take up excessive moisture from the plates is also very good. They are removed at once and dropped through a valve into a pipe with a strong suction, which runs along beside the pasting bench and carries the papers to the furnace room.

In most pasting rooms there is an exhaust placed at the bench, usually along the far edge. This is probably of some value but it is not so important as dampness of surfaces and strict precautions against the formation of oxide dust, nor is a draft needed at this point so much as at benches where pasted plates are stacked.

It is unnecessary to describe bad conditions in pasting rooms. These are only too likely to occur, even if the management is fairly desirous to protect its employees, while in the absence of such good intentions conditions may become outrageously bad.

Drying or Pickling Plates.—Pasted plates must be transported, perhaps to the drying room, perhaps to the pickling or forming or storage departments; this work may be a very dusty job and may result in scattering oxide dust in departments where no actual oxide work is done. Much more handling of these plates is often seen than would appear to an outsider to be necessary. To lift them by hand from the pasting bench to a truck and then to lift them out again and pack them in another receptacle or lay them on shelves for storage or drying would seem to be an inefficient method and is certainly a dangerous one. It is unfortunately a common experience to find oxide dust along hallways, accumulating in corners, spread over empty benches, over shelves, and over trucks; all this is preventable. Here again the system used by the Prest-O-Lite Company is worthy of praise. The pasted plates are carried along a traveling belt, and while they are still wet they are placed in boxes with handles and are dried in these without further handling. They go to the storage room—a light, clean room with a damp floor—in the same boxes which are conveyed along traveling belts and need no handling. As soon as a box is emptied it is washed out. A very clever device keeps all these traveling belts wet and clean. This is a stiff brush which is fastened with a counterweight below the belt; it dips into a pan of water and brushes the belt as it passes down on its return journey.

It is a distinct advantage to pickle the pasted plates at once without drying them, and then while they are still damp to put them through the finishing department and assemble them in batteries. In this way much dusty work is avoided. Pickling is done in order to make a smooth surface on the pasted plate which otherwise may crack as it drys, and a pickled plate is far more solid and dustless than one which has not been through an acid bath.

The Westinghouse Union Battery Company has a satisfactory method. The pasted plates go while moist into a pickling tank, the acid is pumped in, at the end of the day it is pumped out, the tank is covered, and hot air is

driven in so that by morning the plates are dry. This is the only drying that is done. The big storeroom for these pickled plates is clean, the floor is wet, and no dust is evident anywhere, not even on the trucks. The battery of pickled plates is built up at once and is then formed, so that there is no storing or handling of dusty formed plates; the only stock on hand is pickled plates and finished batteries. The Vesta Storage Battery Company also pickles and assembles without drying all plates except those that are to be shipped as plates.

In the Willard Storage Battery plant, drying necessitates very little handling of the plates. The pasters place them on trucks which are run into a heated tunnel, 240 feet long, through which they pass slowly, coming out dry and passing, without removal from the truck, to the forming room.

Formation.—There may be much oxide dust produced by carrying the dry pasted plates to the formation room and taking them out of the receptacles and placing them in the acid. In one otherwise good plant I followed a path of brown peroxide dust from the drying room to the forming tanks, and the unused trucks that stood about were covered with this dust. This is the only real risk in the formation room, for so far as we know the sulphuric acid spray in the air is not dangerous to health. It is caused by the evolution of gases—oxygen from the positive plate and hydrogen from the negative—and though it is not harmful it is distinctly disagreeable; therefore it is gratifying to see that efforts are made in some plants to minimize the fumes. In the Crescentville plant, formation is divided into different units so that men do not have to face very heavy fumes. In the Prest-O-Lite plant there is a separate room for forming negative dummies; as a result, the big forming room is unusually free from fumes. It is a mistake to carry on inspection, or any of the processes of finishing, as is done in one large plant, in the forming room. This introduces unnecessary risks into what should be fairly safe work.

Storing.—The storing of dry pasted plates may be a source of decided danger, if the storage room is dirty and neglected or if there is no storage room and the plates accumulate in the different workrooms or in hallways. In one large plant great quantities of plates are stored in the pasting room. In another plant they stand on shelves or in open trucks in passageways and in finishing and assembling rooms. A very good storage room is in the Willard Storage Battery plant, where the floor is kept damp by sprinkling with magnesium sulphate. Another is in the plant of the Prest-O-Lite Company. This is a light, clean room with a wet floor, and the pasted plates come from the pasting room in clean boxes conveyed along a traveling belt. They are stored in these boxes and each box is washed as soon as it is empty.

Finishing.—The finishing room may be a very bad department, with brown peroxide dust over benches and floor and all possible surfaces, or it may be scrupulously clean. The amount of finishing required varies much in the different plants. In some plants, for instance in the Vesta Storage Battery Company, the pasted plate is simply

put through a punch press which cuts the pairs apart, trims the edge, and slices off the end of the lug, leaving a clean surface. In most plants, however, the lug is brushed or scraped in order to free it from oxides and to produce a clean surface for lead burning. This is still done by hand to a certain extent, and sometimes without any provision for the protection of the cleaner. In one large plant the dust lies thick in the finishing room.

Very good conditions are, however, found in some plants. Thus, in the Willard Storage Battery Company the floor is kept damp and the men stand on platforms; there is no handwork at all, and the machines are enclosed with an exhaust hood. The benches are of perforated plates with an exhaust below. In the Prest-O-Lite Company, the floor is covered with wet sawdust, and there is an enormous exhaust system for the dust. A new machine, completely enclosed, which had just been installed, saws the plates apart and trims and scrapes the lugs and the edges of the plates. The finished plates go on a traveling belt which is kept wet and clean by passing over a stiff, wet scrubbing brush. In a second room, with sawdust covered floor and the same form of traveling belt, lugs are cleaned by hand at a bench with a perforated top and a down draft.

Inspection of the finished plates belongs to this department and should be carried on under an exhaust hood provided with a pane of glass, under which the man can work, or on a perforated bench with a down draft exhaust. It is important to have such benches for all the work of finishing. For instance, in one plant which has excellent mechanical finishing, the take-off bench is solid; as the man drops the finished plates and then bunches them together, the dust falls off and accumulates rapidly on the bench.

Lead Burning or Element Burning.—The Prest-O-Lite Company has an excellent one-storied building, with a monitor roof, windows on all sides, a smooth floor kept continuously wet, and traveling conveyors and benches also kept clean and wet. The Philadelphia Storage Battery Company has its lead burning done at benches with perforated tops, with down suction and a collector below to catch the dust which can be easily cleaned out. In the Willard Storage Battery Company there is an excellent department, with mechanical conveying and burning. The benches have perforated plates, with down suction, the floor is wet, the men stand on platforms, and there is ample ventilation. Traveling belts carry the plates to be racked up and have straps put in, then they pass on under gas flames set at different angles, with one man to do the touching up. When the plates must be handled, it is done on a perforated plate at a bench with two exhausts, one horizontal and one upright. The Crescentville plant also burns connections by machine, in a light, well-ventilated, and very clean room. There is a good down draft under the machine, the floor is smooth and damp and is swept twice a day with wet sawdust, the men stand on clean platforms, and the benches where the units are taken off on the conveyor are slotted, with a down draft.

In connection with lead burning it

may be interesting to refer to a recent German article which describes experiments made with flames of various compositions which are used by lead burners, with a view to discovering which flame produces the greatest volatilization of lead.[8] The experimenters found that the oxyhydrogen flame caused much more volatilization of lead, and consequent contamination of the air with lead oxides, than the oxyacetylene flame, although the latter is far hotter. The volatilization of lead is in proportion to the oxidizing property of the flame, much more than to its heat. The acetylene flame oxidizes less than the oxyacetylene and much less than the oxyhydrogen, but if a hydrocarbon such as benzene or illuminating gas—which always contains hydrocarbons—be added to the oxyhydrogen flame, the volatilization of lead is much lessened, and the same effect is produced by the addition of acetylene. The greatest amount of lead oxide is produced by an oxyhydrogen blowpipe with an excess of oxygen, a very common variety for lead burning; the least is produced by a quietly burning, faintly luminous flame containing a hydrocarbon, such as oxyacetylene, oxygen-illuminating gas, or oxyhydrogen with a hydrocarbon.

Of the nine factories under discussion, only three use the least desirable kind of flame, the oxyhydrogen, and in two of these it is employed only for certain jobs, for others hydrogen-air is used, but for most of the lead burning, oxygen-illuminating gas is the flame selected. Two plants use oxygen-illuminating gas for all work, one uses it and also oxyacetylene gas, and three use the last named altogether.

Smelting Dross.—This work is recognized as more dangerous than any of the processes of manufacture. Thus in one plant where dross is smelted, the men employed in this process are examined by the physician every three weeks, while others are seen only once a month. The risks consist in dust and fumes. The prevention of fumes from the feed door and from the tapping floor is not a difficult problem, and in this particular plant has been well solved by good suction over the feed door and over the lead kettles, while the slag runs out under water to granulate it. It is much more difficult to control fine dust from flues and from a Cottrell precipitator; the latter may have to be cleaned out every day, and the former as often as once in two weeks. This dust is hard to handle safely, for water will not soak into it unless it is first mixed with lime or soda ash. The best procedure seems to be to let a hose play over the dust heap while it is being shoveled into the mixer. In the Prest-O-Lite plant, a bag house is used for dust collection, the cotton bags being enclosed in steel hoppers and mechanically shaken. The dust falls into the end of the hopper and is emptied through a canvas chute. This department is quite dust free.

Salvaging Old and Defective Plates.—Old and defective plates cannot be handled without producing dust, and the salvage department is sometimes the dustiest in the whole plant. The

[8] Engel, H., and Froboese, V.: Untersuchungen zur Klärung der Bleiverflüchtigung beim homogenen Verbleien und Bleilöten unter Verwendung verschiedener Gebläseflammen. Arch. f. Hyg., 1926, *96*, 69; abstr. in THIS JOUR., 1926, *8*, 86.

Vesta Storage Battery Company has a very good arrangement for such work. The plates are shaken free from oxides under a hood which has a window and is lighted from inside. The man strikes the plates against an iron grid and the powder falls to a receptacle below, while the finer dust is drawn down by the exhaust within the hood. The Philadelphia Storage Battery Company keeps the scrap in a separate shed and treats the plates with hot water in order to get rid of the compound, then breaks them apart when they are wet and washes out the oxide paste, which is sold in paste form to a refinery.

Sealing Containers.—Sealing the containers with a compound or composition, consisting chiefly of hot asphalt or tar, is a part of assembling. The fumes of this process are disagreeable enough to make their prevention desirable, and the better plants are quite free from even any odor of tar. The Willard Storage Battery Company has the compound kettles in a separate, closed room on a mezzanine floor, and the compound is fed down to a closed receptacle from which the men fill their funnel shaped cans. The Crescentville plant also delivers the compound from pipes, and the Westinghouse Union Battery Company carries the system even further. The compound, which is melted in an electrically heated kettle, is piped down to a stationary nozzle, and the batteries travel past it. In this plant the burning of top connecters is done under glass in order to prevent the escape of smoke from the compound. The Prest-O-Lite Company has a similar system, the cement mixture running down an electrically heated pipe and flowing, under control, over the batteries.

Floors.—Wooden floors are forbidden in storage battery factories in both England and Germany, for it is impossible to keep them from becoming impregnated with lead oxides. Even impermeable floors, however, do not solve the problem, for they must be kept clean. There are several ways of managing this problem in the better plants. The best method, I should say, is the use of quantities of wet sawdust, as is done by the Prest-O-Lite Company. Next to that I should place the Willard Storage Battery Company's method of continual sprinkling with magnesium sulphate water. The use of a vacuum cleaner may be fairly satisfactory, as it is in the Crescentville plant, where the floor of the pasting room is of smooth composition. It would never be satisfactory for a floor that was not smooth and impervious. Better than this is the floor of the blending room in the Crescentville plant, which is sloped to drains and is flushed four times a day. Far too common in plants in the United States is the wooden floor which quickly becomes rough and cannot be thoroughly cleaned.

Physical Care.—The physical care of the workers in a storage battery plant should include provisions for personal cleanliness and proper shop discipline to enforce their use, provision of clean lunch rooms and wholesome hot food, and a properly organized system of medical supervision including periodic examinations by a qualified physician who must have for his use a well-equipped medical department. Most of these requirements are met by eight of the nine plants, and some of

them go beyond what is required and provide with true lavishness for these essential services. Hot water, soap, towels, and nail brushes are provided in seven plants; six provide shower baths and report no difficulty in getting the men to use them. The washrooms are clean and the plumbing is good.

A good equipment is not, however, the whole story. Supervision is of decided importance. The Westinghouse Union Battery Company requires the lead worker to take two baths a week unless the man has an excuse from the doctor. The Exide Company requires the men engaged in filling ironclads to take baths once a week. The Willard Storage Battery Company has a very large and well-equipped department, with two men in charge and a third to give out supplies. There are bubblers of warm water for washing out the mouth and 170 shower baths for 1,200 employees. The baths are in a warm room, and the nozzle is fixed at one side instead of overhead. The men are allowed to come at any hour for a bath and are said to use these provisions gladly. The best feature in this plant is that the lockers for the working clothes and street clothes are in the washroom, so that the men must go there before eating lunch or quitting. This is a very important feature and should be copied by any company which is installing a new washroom.

Five plants have excellent cafeterias with hot dishes at reasonable prices, but the men may, if they wish, bring their own lunches. They are encouraged to buy milk. Several plants endeavor to enforce strictly the rule against eating lunch in the workroom and with unwashed hands, but on the whole it cannot be said that storage battery works in the United States have as yet as good discipline in this regard as have those in England, yet here is a trade in which personal cleanliness is of peculiar importance because it is impossible for the men to keep their hands quite free from lead oxides unless they work all the time in perfectly dust proof rubber gloves.

Working clothes (washable overalls) are provided by only three companies, although a fourth provides them for pasters, molders, and smelters. This provision is considered by the British and by the Germans as an essential part of the physical care of the men.

Women are employed to a very slight extent in storage battery plants in the United States. Five plants do not employ any women. Three have women in the casting room, and one employs them in inserting separators and in small soldering jobs. It is noteworthy that lads are seldom seen in any of these factories.

Medical Department.—Every one of the plants has a medical department of some kind and provides some form of medical service, which in the majority is apparently quite adequate; in at least two, exceptionally good. Periodic examinations are made by men of some experience with lead poisoning, and as a usual thing the rooms provided for the doctor are large and well equipped. It is the rule for the physician to be given authority to order a change of work for any man who in his opinion has or is in danger of developing lead poisoning, and the ideal of all is

to detect the latter in a very early stage.

An excellent addition to the medical supervision is careful instruction of the workers themselves, and this is done at the Prest-O-Lite plant, where one sees in the washrooms and in the employment office large printed placards explaining in simple language the dangers of lead work and the proper precautions to be taken by men engaged in it. Besides this, the medical department instructs each new man in the dangers of his particular job, and the foreman follows this up with continual instructing.

The records which I have been able to obtain show very clearly the effect of the great improvements that have been introduced in the storage battery industry in recent years. Thus the Prest-O-Lite Company reports that in 1918 when conditions were most unsatisfactory there were 96 cases of recognized lead poisoning, an average of 8 per month with 1,000 employees on the payroll. This would make a yearly rate of 9.6 per hundred employees. The records for the first nine months of 1926 (under new management) show a total of 9 cases, an average of 1 per month with 1,350 on the payroll, which would give an average of 0.88 per hundred employees per year.

The Westinghouse Union Battery Company has had the following record during the past three years:

Year	*Number of Cases*	*Number Employed*	*Rate per Hundred*
1924.....	60	400	15.0
1925.....	12	275	4.3
1926.....	7–8	320	2.4[1]

[1] Calculated for the year on the report up to May 20, when three cases had occurred.

The character of the disease is almost always of the acute or gastric type. Dr. William V. Boyle, of the Prest-O-Lite Company, reports fully 98 per cent. of his cases as belonging to this type; only 2 per cent. are cases of palsy. He has not treated any case of lead encephalopathy. The younger men aged from 18 to 24 years are likely to succumb more quickly than the mature men. Dr. Boyle considers the comparative danger of the different operations to be as follows: first, pasting and mixing; second, plate inspection; third, finishing and salvaging; fourth, assembling and lead burning; fifth, plate stock; sixth, molding.

Dr. Erle F. Smith of the Westinghouse Union Battery Company has had no case of lead poisoning among molders for four years. He finds that the highest incidence of poisoning is in the finishing department among those engaged in cutting pasted plates and buffing or polishing lugs; lead refining ranks as a close second, inspection third, and pasting fourth. This is on the basis of the average of 10,000 hours' exposure. The average age of the men in the lead departments is 28.3 years, but the average age of the men presenting cases of lead poisoning is only 25.6 years. The shortest period of exposure—forty-three days—was in the refining department; then came finishing and pasting, both with fifty-seven days. In assembling, the exposure averaged almost four months; and the one molder who developed lead poisoning had worked eleven months and five days.

In 1926 only three cases were recorded up to May 20, when I made my visit to the plant. Even these

might not have been included under a less strict physician, for only one man had abdominal cramps and a lead line; the second was suspended for a month and ordered to have his tonsils removed, as a result of which the pallor and albuminuria which had aroused suspicion cleared up; the third case was transferred to work free from lead because of pallor, 70 per cent. of hemoglobin, and the appearance of three stippled blood cells to a microscopic field.

The employment of Negroes in lead work is always a mistake, for they are apparently more susceptible to lead than are white men and certainly more liable to the cerebral form of plumbism. It will be interesting to see whether the Filipinos who are entering this industry very rapidly will prove to resemble Negroes or white men in their susceptibility to lead.

In addition to these nine large factories, a list has been given me of some 290 smaller plants, all of which do more or less manufacturing of storage batteries. The problem in these smaller plants is the same as in the larger, and, as is true in every industry, in the smaller plants the precautions used are likely to be less adequate than in the larger, and medical care quite lacking. It is probable that a greater proportion of the men employed in small storage battery plants contract lead poisoning than of those employed in larger plants, but no thorough study of the small plants has ever been made. The danger of the storage battery extends beyond the industry itself, for the dustiest scrap in a refinery is likely to be the heap of old storage battery plates, and even in junk shops which simply collect scrap these plates may be productive of lead poisoning. In one junk shop in Boston where scrap is simply collected, not treated, four severe cases of lead poisoning developed as a result of handling old battery plates.

Summary

The making of storage batteries (electric accumulators) is a lead trade accompanied by more than the average risk of lead poisoning because of the presence of large quantities of lead oxides and also, though to a lesser degree, because of fumes of lead from kettles and from lead burning operations.

The present investigation concerns nine large factories in the United States, four in England, and one in Germany. The plants in the United States employ from 7,000 to 8,000 men in lead work. The problem of protecting them from lead poisoning is far from simple, owing to the nature of the work, and it requires provisions for the prevention of lead oxide dust and lead fumes, for personal cleanliness of the workers, and for proper medical supervision and treatment of the individual.

A comparison between the industry in the United States and in England and Germany shows that the advantages on the side of the foreign countries consist in the greater proportion of stationary batteries manufactured there, which means less exposure to lead oxides, and the higher standard of governmental sanitary control, which is based on expert

knowledge and enforced by competent inspectors. The advantages on the side of the United States consist in the greater use of mechanical devices to displace handwork, the general use of oil or electric heat instead of gas or coal, and the very small number of women and lads employed.

BOOK REVIEW

VENTILATION AND HEALTH. THE NEW HYGIENE OF FRESH AIR. By *Thomas D. Wood*, A.M., M.D., Professor of Physical Education and Adviser in Health Education, Teachers College, Columbia University, New York; Author of "Health and Education," and "The Child in School," and Co-Author of "Byways to Health," etc.: and *Ethel M. Hendriksen*, Former Executive Secretary, Tuberculosis and Public Health Association of Rochester and Monroe County, New York. Cloth. Pp. xvii, 210 with glossary and index, illustrated. New York and London: D. Appleton & Co., 1927.

Any reader who is familiar with the existing controversy between natural and mechanical ventilation as applied to schoolrooms will be interested to find how forcibly the authors join Prof. C.-E. A. Winslow of Yale University in his campaign against mechanical ventilation. In fact they surpass Winslow in claims for what they call the most scientific system of ventilation. Thus they state (p. ix) "There is ample evidence to prove that modified window ventilation can be used successfully in factories, offices, stores, theaters, churches, hospitals, dispensaries, and private dwellings, as well as in schools." From Winslow, on the other hand, we have the following conservative statement:[1] "It must be clearly understood, however, that the conclusions I am enunciating bear only on the average schoolroom, so situated that the application of the system of modified window ventilation can be safely and conveniently applied. In the auditorium and in the large office or crowded factory workroom conditions are wholly different. In a room containing much more than 50 people, ventilation by the modified gravity system would generally prove inadequate in view of the difficulties of securing a properly distributed air change throughout the room and in view of the excess of heat production within the room as compared with heat loss through its walls. For such an occupied space, plenum ventilation offers as I see it the only possible remedy . . . ." (pp. 119–120).

Although this book is intended to describe to the layman the latest scientific principles of ventilation, it is disquieting to observe how little the authors are informed regarding the modern researches on the subject. For example they state in their preface (p. viii): "So far as is known, no university or medical school in this country conducts research work in ventilation, although work of this nature has been undertaken by the

[1] Winslow, C.-E. A.: Objectives and Standards of Ventilation. Jour. Am. Soc. Heating and Ventil. Eng., 1926, *32*, 113.

United States Bureau of Mines, devoted almost wholly to industry." The authors ignore the work done during the past five years at the Research Laboratory of the American Society of Heating and Ventilating Engineers in co-operation with the United States Bureau of Mines and the work of the United States Public Health Service. They apparently are not familiar with the researches carried on at the Johns Hopkins School of Hygiene and Public Health, at the Columbia Institute of Public Health, at the Yale School of Medicine, and at the Harvard School of Public Health.

It is possible to excuse an occasional misprint in the first edition of any book, but absurdities like the following cannot be condoned:

"The anemometer [Vernon's hot wire type] is a small instrument which stands upon a table. It is equipped with copper wires which are attached to a battery. As these wires grow hot, a current of air directed against them will be manifest by the visible cooling of the wire" (pp. 174–175).

"He [Pettenkofer] said that 0.6 cubic feet per hour per pound weight, was the approximate amount of carbon dioxide in expired breath" (p. 34).

In referring to wet and dry bulb thermometer readings: "If room air is very dry the difference will be very little and if it is full of vapor, as from a steaming kettle, the difference will be marked" (p. 174).

Many other statements of like nature could be quoted.

It is unfortunate that so inaccurate a book should be presented to the public in the guise of popular science. —*Philip Drinker.*